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CONTENTS

Number 1

Third British Empire Forestry Conference (Australia and New Zealand, 1928). By R. L. ROBINSON 5

Relationship between Silviculture and the Utilization of Timber . . 13

Cost of Production of Timber in Britain. By W. E. HILEY 17

The Multiple Mycorrhizas of Trees. By M. C. RAYNER 26

Waste Lands of North Wales. By G. W. ROBINSON 33

Oak Mildew and its Control in Forest Nurseries. By R. C. WOODWARD, J. S. L. WALDIE, and H. M. STEVEN. With Plates I and II . . 38

Woodworking Machinery, with Special Reference to the Building Trade. By W. E. WILSON 57

The Biology and Control of *Hylobius abietis*. By J. W. MUNRO . . 61

REVIEWS:

Recent Research on the Root-systems of Trees. By R. N. ALDRICH-BLAKE 66

Recent Research on Stem Form. By JAMES MACDONALD 70

Recent Research on Forest Drainage. By H. M. STEVEN 73

Foundations of Silviculture (J. W. TOUMEY). By H. M. STEVEN . . 75

Engineering for Forest Rangers (A. H. LLOYD). By F. A. LEETE . . 76

NOTICES:

The Forest Industry of Finland (W. E. HILEY) 77

Aerial Survey in Relation to the Economic Development of New Countries (R. BOURNE) 77

Report on Census of Woodlands and Census of Production of Home-grown Timber, 1924 78

Growth and Yield of Conifers in Great Britain 78

Nursery Investigations (H. M. STEVEN) 79

Lyctus Powder-post Beetles (R. C. FISHER) 80

Number 2

Address to Society. By the PRESIDENT 81

The Second Annual Excursion of the Society 85

Environment and Disease, a Discussion on the Parasitism of *Armillaria mellea* Vahl. Fr. By W. R. DAY 94

Silvicultural Research in India, its Organization, Problems, and Methods. By H. G. CHAMPION 104

Forest Soil Science in Sweden. By G. V. JACKS 118

Afforestation in South Africa. By H. M. STEVEN 124

A Report on the Proceedings of the Seventh International Congress of Forest Research Stations, held in Stockholm, July 1929. By W. H. GUILLEBAUD 134

The Forestry Sub-Section of the British Association Meeting, South Africa, 1929 142

REVIEWS :

The Structure and Life of Forest Trees (BÜSGEN, MÜNCH, THOMSON). By R. N. ALDRICH-BLAKE 144

The Role of Research in the Development of Forestry in North America (I. W. BAILEY and H. A. SPOEHR). By the EDITOR 145

British Hardwoods (L. CHALK and B. J. RENDLE). By S. H. CLARKE . . 146

Forestry (A. B. RECHNAGEL and S. N. SPRING). By W. L. TAYLOR . . 147

Le pin Weymouth en Suisse (H. BADOUX), and Holz, Blattmenge und Zuwachs. I. Die Weymouthsföhre (HANS BURGER). By the EDITOR . 147

Untersuchungen über die Weisstannenlaus *Dreyfusia nusslini* C. B. in der Schweiz (O. SCHNEIDER-ORELLI, C. SCHAEFFER, and R. WIESMANN). By R. N. CHRYSTAL 148

Plant Ecology (J. E. WEAVER and F. E. CLEMENTS). By the EDITOR . . 149

NOTICES :

Report of the Forest Products Research Board for the Period ending 30th September 1928 151

The Practice of Silviculture (R. C. HAWLEY) 151

Le Sol et la Forêt (E. HESS) 151

Notes on some Forest (Site) Types in North America (YRJÖ ILVESSALO) . 154

A Tree Classification and Thinning System (LAURI ILVESSALO) . . 154

THIRD BRITISH EMPIRE FORESTRY CONFERENCE

(*Australia and New Zealand 1928*).

BY R. L. ROBINSON

THIS Conference opened in Perth, Western Australia, on 22nd August and concluded at Auckland on 23rd October 1928. Lord Clinton, Chairman of the British Forestry Commission, presided over a body of foresters which was on the whole more representative of the Empire than was the case in either of the preceding conferences, the only notable region without delegates being the West Indies. The Australian and New Zealand authorities arranged and carried out with admirable precision a lengthy series of tours which embraced the principal of the more accessible forest regions of all six States of Australia and both Islands of New Zealand. Discussions were held in each of the capital cities and at some intermediate points, and since the Conference had a heavy agenda involving much committee work, and hospitality was very freely tendered on every side, delegates found little spare time on their hands.

Any attempt to describe in a short article the various forests of Australia and New Zealand is foredoomed to failure, and it is proposed to offer merely a few broad comments. In the course of roughly a century Australia has drawn heavily on her resources of hardwoods (Eucalypts), and has gone far towards depleting her original stands of softwoods, which were never very large. Much of the destruction in so far as it made room for settlement was inevitable, but not a little was due to ignorance and carelessness which have allowed fire and unregulated grazing to ruin regeneration.

These wasteful processes are by no means at an end, but Australia has apparently become sufficiently aware of the position to realize that some thought has to be taken for the future, although she has not yet reached the stage of grappling firmly with the problems of policy and technique. In Western Australia steps are being taken to limit the cut of the principal species, jarrah and karri, to a figure more closely related than hitherto to the increment, and to protect and encourage new growth by silvicultural methods. In Queensland also the cut of softwoods, hoop and bunya pine, has been limited, and regeneration with these species started on a semi-commercial scale. Victoria and New South Wales are practising on a limited scale regeneration and improvement thinnings in their hardwood forests, and some afforestation with softwoods is proceeding. Over all there is the feeling that conifers must be grown on a far wider scale. Exotics are being widely planted (except in Queensland). The most remarkable plantations visited were those of the Penola-Mt. Gambier district of South Australia—where *Pinus insignis* is making very rapid growth. In her search for the best conifers to suit the

very variable climatic conditions Australia has yet to go far. It is gradually becoming apparent that a general solution will not be found with the much-boomed *P. insignis*, which requires special locality conditions for healthy growth. Tasmania, which from its geographical situation should possess at least the best climate for the growth of conifers, has very little to show in the way of plantations and nothing of forest management.

In brief, it would appear that Australia will seek a solution of her forest problems by a mixed programme of maintaining the indigenous forests and introducing exotic conifers.

New Zealand, on the other hand, has come down heavily, and somewhat rashly in the opinion of many of the delegates, on an afforestation policy to the neglect of the indigenous forests. The reasons are that while the kauri and podocarp forests are difficult to regenerate and slow in growth, afforestation in certain districts is easy and the growth of exotics very rapid. It does not appear, however, that very serious thought has yet been given to the treatment of the indigenous forests, nor to the problems, such as thinnings, which are likely to accumulate with vast tracts of even-aged and mostly pure plantations. Nevertheless, it is a fact that the afforestation conditions in the extensive pumice areas of the Rotorua district (North Island) are extremely favourable. Six or seven hundred seedling *P. insignis*, or Douglas fir, are sufficient to start a plantation which requires little or no weeding, fencing or protection, rapidly develops a canopy, and proceeds to produce timber at a great rate. Other species, such as ponderosa, Corsican, and white pines, redwood and larch, also show excellent growth.

In both Australia and New Zealand there have been formed in recent years a considerable number of afforestation companies. Most of these, but not all, are concerned with *P. insignis*, from which wonderful financial returns are predicted. The data on which these companies for the most part base their estimates of profit will rarely bear critical examination, and in some cases no examination at all.

THE DISCUSSIONS OF THE CONFERENCE.

In reviewing the position of forestry since the Canadian Conference of 1923, delegates were able to report substantial progress in most cases. That the Conference is a living and effective organization was shown by the encouraging extent to which its resolutions have been carried out. The chief cause for disappointment lay in the lack of progress in silviculture in Canada.

The discussions of the Conference are mainly crystallized in its Resolutions, a copy of which, extracted from an advance edition of the 'Summary Report, Resolutions, and Reports of Committees' of the Conference, is appended. Certain of the Resolutions approving the Reports of Committees of the Conference convey very little unless read with the Committee Reports, and it is proposed to say a few words about them.

Forest Policy: While there was no committee on this subject, a very interesting debate was held in full conference. The essentials of forest policy which

were laid down by the first Conference in 1920 stood the test of discussion well, and have been accepted almost universally as the creed of Empire foresters. Those additions which appear in the Resolutions, though undoubtedly important, refer mainly to local and special cases.

Australian and New Zealand Forestry. The Committee's report deals first with the historical aspect of Australian forestry, the question of timber supplies, forest management, firewood and other supplies, forest area, research, fire control, plantations of softwoods, thinnings, staff and finance, and then proceeds to deal in some detail with the forests of the Commonwealth territories and of the individual States of the Commonwealth. There is also an addendum on the marketing of Australian timbers. The New Zealand report deals with the indigenous forests and their management, plantations of exotics, thinning in plantations, staff, and the marketing of New Zealand timbers.

In both reports the Committees find room for criticism as well as for commendation, and their recommendations should be of distinct value to the Governments concerned.

Education. The whole opinion of the Conference was in favour of concentrating forestry training at a small number of really efficient schools, that is, in favour of centralization as against the decentralization tendencies hitherto in evidence. It was agreed that the Imperial Forestry Institute has done valuable work on all the main lines on which it was designed to function, and that it ought now to be placed on a permanent basis. Forestry education in Australia received special attention, and after a good deal of discussion it was finally agreed that the higher education of forest officers should be concentrated at the Commonwealth Forestry School at Canberra, the preliminary training and science subjects being taken at a university, and the combined course leading up to a university degree. The discussion on forestry education in New Zealand turned on the advisability of having one instead of two schools in that Dominion. The Conference was emphatic that only one school was required, but was unwilling, on principle, to express an opinion regarding the relative merits of Auckland and Christchurch.

Imperial Forestry Bureau. In a preliminary discussion the Conference decided that in view of the various organizations which have arisen since it was first proposed to set up a Bureau, it should now be possible to distribute the proposed work among existing institutions. The Committee reported that the expressed wish of the Conference to devise some means of collecting and disseminating information on forestry subjects and similar functions falling to a Bureau could be met in part by the Imperial Forestry Institute, the Forest Products Research Laboratory at Princes Risborough and the Empire Forestry Association, and that any further assistance required in the marketing of timber should be given by an Empire Timber Office to be set up in the City of London under the auspices of the Empire Marketing Board. The cost of the additional work, apart from the Timber Office, was estimated at £2,500 per annum, and the Governments of the Empire were urged to contribute each its share towards that sum.

Forest Products Research. That this subject received more attention than at the previous conferences was some measure of the progress made in the last few years. While the representation by forest products research workers left a good deal to be desired, it was possible, nevertheless, to make a comprehensive review of the work done in the various parts of the Empire. It is hoped that in future conferences it will be possible to give more attention to the technical aspects of this subject, which is of first-class importance to foresters. The Committee which reported on Forest Products Research and Empire Trade affirmed the necessity of the forest products laboratories within the Empire keeping in close touch with a view to exchange of publications and information. They thought that further use might be made of Princes Risborough, particularly in connexion with the Colonies which have no forest products laboratories of their own. They also touched on the question of preferential tariffs.

Exotics. A great deal of useful information was placed before the Conference in response to a questionnaire drawn up by the Standing Committee on Empire Forestry and issued early in 1928. The Committee on Exotics, after an analysis of the results and in view of the limited time at its disposal, contented itself with a brief statement on the most important exotic species which had been tried within the Empire, and left the full question to be dealt with by the Imperial Forestry Institute.

Technical Terms and Trade Names. Useful work was done by the two Committees sitting on these subjects.

Other important subjects which received attention, but were not remitted to Committees, were: Research into the Living Tree and Forest, Forest Finance, Labour in Relation to Forestry, and Forests in Relation to Climate and Erosion. A great number of papers containing a store of useful information on these (as on other subjects already touched upon) were presented to the Conference, and will shortly be available in printed form. The debate on Forest Finance was particularly interesting, since it goes to the root of policy, while that on Erosion was very timely in view of the attention which the denudation of the catchment area of the River Murray is attracting.

It is not possible in close retrospect to assess the value of a conference such as this at its true worth. The field is so wide and the issues at stake so important that any conference which could once and for all deal effectively with the whole would indeed deserve well of the Empire. Rather must we look for a gradual improvement in policy (as has already happened), until each individual part of the Empire is definitely on the right lines. Concurrently with, and in continuation of the stabilization and development of policy, is the improvement of forest technique in all its branches. There is consequently ample scope for future conferences.

RESOLUTIONS

RESOLUTION NO. 1.—FOREST POLICY.

This Conference reaffirms Resolution No. 1 * of the British Empire Forestry Conference of 1920, and urges those Governments which have not already acted on them to do so without delay.

The Conference also desires to draw attention to certain aspects of forest policy which, although not all of universal application, are of great importance in some parts of the Empire:

(*a*) It is of paramount importance to lay down and adhere to a definite and permanent general policy. Forestry has imperial and national, as well as local aspects, and forest policy, except where existing constitutional procedure directs otherwise, should be laid down by the Central Government who, further, should exercise control over legislation, management, the alienation of land dedicated to forestry, research, and the training and recruitment of a superior staff.

(*b*) Forest legislation may suitably provide for the protection of water supplies for human consumption, agriculture, and other purposes; for

* This resolution reads as follows:

1. *Forest Policy.*

'In view of the great importance to the Empire as a whole, as well as to each of its component parts, of producing a sustained yield of all classes of timber, of encouraging the most economical utilization of timber and other forest products, and of maintaining and improving climatic conditions in the interests of agriculture and water supply, each of the Governments of the Empire should lay down a definite forest policy to be administered by a properly constituted and adequate forest service.

2. *Survey of Resources.*

The foundation of a stable forest policy for the Empire and for its component parts must be the collection, co-ordination, and dissemination of facts as to the existing state of the forests and the current and prospective demands on them.

3. *Constitution and Status.*

In order to attain continuity in the development of forest resources it is desirable that certain elements of stability be secured in the constitution of the forest policy. This may be done by the following measures:

(1) The definition (where this has not been done already) of forest policy in a Forestry Act or Ordinance.

(2) The reservation for the purpose of economic management and development of forest land under conditions which prevent the alienation of any which is primarily suitable for forest except for reasons consistent with the maintenance of the forest policy as a whole.

(3) The assurance to the forest authority of funds sufficient to carry out the accepted policy for a series of years.

(4) The grant to members of the forestry services of the status of civil servants with due provision for pension.

(5) The appointment as the chief officers of the forestry service of persons having a high standard of training in forestry, their selection and promotion being by merit alone.

(6) The establishment in each of the larger parts of the Empire and for the Colonies not possessing responsible government collectively of an officer or officers, having special duties of advising as to forest policy and surveying its execution.'

the prevention of erosion; for the control of shifting cultivation, whether on private or public land, and for the better management of private forests.

(*c*) Provision should be made for the dedication and afforestation of areas near centres of consumption and to meet agricultural requirements. In this connexion it may sometimes be necessary to make use of land fit for agriculture.

(*d*) The management of forests serving local or communal purposes should be in the hands of trained staff working under the forest authority.

(*e*) Experience has proved that while complete co-operation between the forestry and other branches of the public services is highly desirable, it is short-sighted economy to amalgamate forestry and agriculture in one administrative service.

(*f*) The relations of a forest department with other Government departments should be on a strictly commercial basis.

(*g*) Public education is required as to the importance of forests and forestry, and it is suggested that elementary instruction on the subject be given in primary and secondary schools.

(*h*) The Conference also commends to the notice of Governments the course of instruction in forest policy given at the Oxford School of Forestry to probationers for the tropical African Administrative Services.

RESOLUTION NO. 2.—AUSTRALIAN FORESTRY.

This Conference approves the report of its Committees on Australian Forestry (Appendix II), which it desires to bring to the notice of the Governments of the Commonwealth and of the various States for consideration and action.

RESOLUTION NO. 3.—NEW ZEALAND FORESTRY.

This Conference approves the report of its Committee on New Zealand Forestry (Appendix III), and commends it to the attention of the Dominion Government for consideration and action.

RESOLUTION NO. 4.—EDUCATION.

This Conference approves the report of its Education Committee (Appendix IV), which deals with the training of forest officers in general and forest education in Australia and New Zealand in particular.

The Conference considers that the decision to set up the Imperial Forestry Institute, as recommended by the Empire Forestry Conferences of 1920 and 1923, has been fully justified by results. It strongly recommends that steps be taken forthwith to obtain from the Governments of the Empire such financial and other support as will place the Institute on a permanent footing and fully equip it for its work.

RESOLUTION NO. 5.—FOREST TECHNIQUE.

This Conference approves the Report of its Committee on Forest Technique (Appendix V), and desires to draw the attention of all Governments to the

necessity of bringing their forest estates under organized management as soon as possible, with a view to ensuring a sustained yield of forest products, perpetuating timber and other industries dependent on forests and assisting agriculture.

Further, management being dependent upon a sound knowledge of the requirements of the species, emphasis is laid on the necessity for silvicultural research.

RESOLUTION NO. 6.—IMPERIAL FORESTRY BUREAU.

This Conference, acting on an instruction of the Imperial Conference of 1926, has considered the Resolution of the 1920 Forestry Conference and the discussions by the 1923 Conference, and, in the light of developments which have since taken place, now approves the report of its Committee on the subject (Appendix VI).

It has not been found necessary to recommend the establishment of a separate Bureau, as the work can conveniently be distributed among existing institutions.

In view of the definite benefits which will be derived by each unit of the Empire from the organization now proposed, the Conference recommends that all Governments give it their fullest support.

RESOLUTION NO. 7.—REPORT OF THE IMPERIAL ECONOMIC COMMITTEE ON TIMBER.—FOREST PRODUCTS RESEARCH.

This Conference reaffirms paragraph 1* of Resolution No. 3 of the 1923 Conference, and welcomes Report No. 10 on Timber, issued by the Imperial Economic Committee, with which it is in general agreement.

The Conference approves the report of its Committee on Forest Products Research (Appendix VII), and commends it to the various Governments of the Empire.

RESOLUTION NO. 8.—EXOTICS.

This Conference approves the Report of its Committee on Exotics (Appendix VIII): it requests the Imperial Forestry Institute to complete the inquiry already set on foot, and the Forest Authorities of the Empire to render the Institute every assistance in its task.

RESOLUTION NO. 9.—TECHNICAL TERMS USED IN FOREST MANAGEMENT.

This Conference approves the Report of its Committee on Technical Terms used in forest management (Appendix IX), and trusts that these terms will be brought into use by the Forest Authorities of the Empire.

RESOLUTION NO. 10.—TRADE NAMES OF EMPIRE TIMBERS.

This Conference approves the Report of its Committee on Trade Names of Empire Timbers (Appendix X), and requests the Empire Forestry Association—

1. To publish and distribute the list in the manner suggested by the Committee.
2. To revise and republish the list from time to time.

* The paragraph referred to reads as follows:

'The Conference is of the opinion that the Empire requirements of timber and other forest products should be supplied to the greatest extent from resources within the Empire.'

It trusts that the list of trade names will be regarded as authoritative by all bodies interested in the utilization of timber, and suggests that similar lists be published by all parts of the Empire.

The Conference desires to thank the Empire Forestry Association for the work which it has done.

RESOLUTION NO. 11.—NEXT CONFERENCE.

This Conference accepts the cordial invitation of the Government of the Union of South Africa to hold the Fourth British Empire Forestry Conference in that Dominion in 1933, and desires its Chairman to transmit to the Prime Minister of the Union a suitable message of thanks and appreciation.

RESOLUTION NO. 12 is a vote of thanks and appreciation to Australia and New Zealand.

RELATIONSHIP BETWEEN SILVICULTURE AND THE UTILIZATION OF TIMBER

THE Society decided at the Annual General Meeting in February, 1928, that the excursions of the Society should be undertaken with the object of studying some specific problem, and the one chosen for the First Annual Excursion was 'The Relationship between Silviculture and the Utilization of Timber'. The first of these was studied at Lake Vyrnwy, the catchment area of the Liverpool reservoir in Wales, and the second in and around Liverpool, where visits were made to the timber yards of Messrs. James Webster & Bros., Ltd., Irvin & Sellers, Ltd., Joseph Gardner & Sons, Ltd., and Robert Cox & Co., to the mills of Messrs. Wilson Bros. Bobbin Co., Ltd., and to the Gladstone Dock. The Society is indebted to the Liverpool Corporation and to Mr. Owen J. Sangar, Divisional Officer of the Forestry Commission, for the first part of the programme, and to Mr. Norman Wane, the Secretary of the Liverpool Timber Trade Association, Ltd., who kindly arranged the whole of the second part. The party was entertained to lunch in Liverpool by the Association. Mr. W. E. McKee, of Messrs. James Webster Bros., Ltd., a prominent member of the timber trade in Liverpool, and Professor J. McLean Thompson, of the Hartley Botanical Laboratories, University of Liverpool, were present as guests, and made valuable contributions to the discussions held during the various inspections and to the conference in Liverpool on the last evening of the meeting. The results of these deliberations may be summarized as follows.

REQUIREMENTS OF THE MARKET.

The inspection of the timber stocks at Liverpool, consisting of both temperate and tropical hardwoods and softwoods principally from Canada and the United States, brought home vividly the remarkable variety of species, quality, size, and condition of timber which the life of a modern civilized state requires. In value there was every gradation, from mahogany logs worth £500 each down to the cheapest and lowest grade of home and foreign wood. With such a variety of requirement it should be possible to find a place for almost every class of timber, provided there is a sufficient quantity of it, and it is properly prepared for the market, particularly as regards uniform manufacture and careful seasoning. Even large rough beech imported from Ireland was converted into bobbins and spindles for export to India and elsewhere. If British forestry is to progress there must be mass production sufficient to meet large demands; in fact, the utilization of each class of timber must be undertaken upon an extensive scale with the operation of up-to-date machinery and low costs of manufacture. This does not mean large areas comparable to those overseas.

There might be concentration on a limited number of species, and an endeavour made to produce timber of uniform size to meet the demand for the particular grades and dimensions capable of manufacture from it.

For general purposes the sizes in demand would seem to be lengths of twelve to twenty feet in logs; good width is important, but seven- to nine-inch widths are valuable. The optimum plank thickness is four inches, but three inches and less are acceptable.

During the visit to Liverpool, timber of Canadian yellow (or white) pine (*Pinus strobus*) and western white pine (*Pinus monticola*) was seen of a quality which could not be produced in this country, and will probably not be produced anywhere when the virgin forests from whence they come are depleted. It must be remembered, however, that only the material for what is termed export grades is shipped from lumber-milling countries, and it is estimated that only 50 per cent. of the output is sent here, the balance, consisting of inferior grades, being consumed in the country of origin. On the other hand it was interesting to note that the foreign producer has been able to supply a good percentage of sapwood in a bright and sound condition by special methods of piling and treatment, thus increasing the product of the log.

The following comparative prices for different grades emphasize the importance of offering the best qualities:

Oak in board (mainly American)	Grade 1	5*s.* per cubic foot.
	„ 2	3*s.* 6*d.* „
	„ 3	2*s.* 6*d.* „
Canary whitewood (*Liriodendron tulipifera*)	„ 1	5*s.* „
	„ 2	3*s.* „
	„ 3	2*s.* 3*d.* „
Birch	„ 1	5*s.* 6*d.* „
	„ 2	4*s.* „
	„ 3	2*s.* 6*d.* „

According to width, thickness, &c.

It was considered that timbers could be grown in this country comparable to the imported Canadian Red Pine (*Pinus resinosa*). There will probably be, also, an increasing market in future for spruce, particularly in small sizes, having regard to the development of the pulp market and the new industries dependent on it, such as the manufacture of artificial silk.

An opinion was sought from members of the timber trade upon knots and large ring growth. The consensus of opinion was that wide rings indicating rapid growth was never so serious a defect as knots, at least for joinery work.

The stocks of imported timber emphasized the importance of good manufacture. The market requires well-sawn material with attention to exact size. Clean edging is favoured by buyers. The sale of timber depends in no small measure on the attractiveness of its preparation. There were many examples exemplifying the importance of the proper treatment of timber both in seasoning and storage to prevent twisting, warping, and discolouration.

THE PRODUCTION OF OUR TIMBER REQUIREMENTS.

It is clear that both in quantity and quality we can only produce a moderate part of the national requirements, even in softwoods. There appears, however, no reason why the home production should not become much more important. The home timber trade has had, and will have for a considerable period, very difficult conditions, because much of the largest and best timber was cut during the war, and lots offered for sale are now small and scattered, both operating against efficient manufacture and proper grading. It is to the future, when the produce of present-day afforestation will be ready for marketing, that we must look; and it is of the utmost importance that this produce should be suitable to the needs of the market as far as possible.

In the first instance, we have to consider the species of trees to be grown. If the view is correct that in softwoods the tendency will be towards an increasing demand for whitewoods, the proportion of spruce planted should become greater than hitherto. In hardwoods, oak, beech, birch, ash, walnut, sweet chestnut, and to a less extent elm (*Ulmus racemosa*), are all timbers in which there is a large import trade to-day, and the production of these in suitable sizes and qualities should not be overlooked. But whatever be the species grown, the areas assigned to each ought to be extensive, and so managed that important fellings will occur at regular intervals. Intermittent sales of lots of moderate size will not be sufficient to supply the trade, which requires the steady reliable supply which is the feature of imports.

The timber must be grown reasonably clean and free from knots, whether hardwood or softwood, and the present reputation of home timber must be removed by good silviculture. Knottiness is a defect which, by limiting the possible uses of the timber, markedly decreases its value.

The conclusion was that, especially in Douglas fir and the spruces, artificial pruning up to fourteen feet or more should be done early on selected trees likely to form the final crop.

There is the question of width of ring. The part of the tree with the widest rings is the core, which is also the knottiest, especially in artificially grown trees. This knotty, wide-ringed core will only be useful for inferior purposes. Until canopy closes, branch suppression begins and width of ring decreases, the tree-roots and stem should be viewed as a skeleton or framework for the support of the future timber. The stem should be straight, stable, and healthy, and the first thinnings should be directed to selecting trees with such qualities for future development. Artificial pruning of selected trees will ensure that the timber laid on this skeleton will be free from knots, at least for the first fourteen feet or more, and much can be done by methods and degree of thinnings to control width of ring. At Lake Vyrnwy several instances were seen of the liability of Douglas fir to windfall. This is too large a subject to go into here, but undoubtedly this species should be restricted to well-drained sites, and to stony and rocky soils which appear to increase its wind-firmness.

CO-OPERATION BETWEEN PRODUCER AND USER.

The forester as the producer of timber can undoubtedly gain much by close contact with the timber trade, not only home but foreign. Only by continual contact will it be possible to ensure that the requirements of the market are being met as far as conditions permit. This should also greatly aid in the introduction of home-grown timber into the markets, and its assimilation therein.

Further, this country has much to learn in the manufacture, grading, seasoning, and other preparation of timber for the market, and co-operation between the home timber trade and the importing merchants cannot but lead to improvements.

The Forest Products Research Laboratory, which is in contact with both producers and timber merchants, should constitute an important link in this co-operation. Moreover, one of its principal functions is to improve the methods of preparation of timber.

The Society of Foresters realizes also that it has a part to play in helping in this co-operation, and it is indeed fortunate that its first excursion should have been devoted to making a step towards the ascertainment of what the timber market requires. It is also most encouraging to receive such a warm and sympathetic welcome from an important body like the Liverpool Timber Trade Association.

COST OF PRODUCTION OF TIMBER IN BRITAIN

BY W. E. HILEY

Lecturer in Forestry Economics, Imperial Forestry Institute, Oxford

THE prestige of forestry economics has suffered from the fact that the results of calculations are generally expressed in a form that is unconvincing to practical foresters. In general two methods have been adopted: either it is shown that with certain timber prices, if the rate of growth corresponds with that of a certain yield table, and calculations are made with a certain rate of interest, then the land has a certain *expectation value*; or else it is shown, on the same data, that if land can be bought for a certain price the investment may earn a certain *rate of interest* (financial yield). Both the land expectation value and the rate of interest appear as very academic quantities, and it is only by an effort of the imagination that we can see that they have much significance in practical forestry.

Such calculations would be much more easily understood if they enabled us to estimate the actual *cost of production per cubic foot* of timbers of various species on land of each quality class. There are, however, two difficulties which have stood in the way of such a method of expression. The first difficulty is that by far the largest part of the cost of production of timber is represented by compound interest on the money invested in land, labour, and material, so that the calculated cost of production is greatly affected by the *rate* at which interest is charged to this capital. The second difficulty is that the cost of production of a final crop will depend on the amount of money which has been received for thinnings. This is especially important in the case of larch, and on Quality I larch soils where there exists a good market for thinnings the cost of production, including interest, may be met by the sale of thinnings so that the cost of the final crop may be nil. This difficulty is not confined to forestry, and it is well known that the cost of producing gas depends on the sale of by-products of the gas works and the cost of producing wool depends on the price of mutton.

In the present paper an attempt is made to meet these difficulties. The rate of interest that should be charged is largely a matter of opinion, but it will be generally accepted that for profitable working the rate should be somewhere between 3 and 5 per cent. Calculations have been made at 3, 4, and 5 per cent., and if the reader attaches particular weight to the actual figures of the cost of production, he must make his own choice as to which rate of interest should be charged. As, however, the value of these calculations is comparative rather than absolute, comparisons may be made of the cost of producing various timbers at the same rate of interest and the actual rate chosen is not of very great importance.

The difficulty of the relative price of thinnings and final crop has been met by assuming that the standing price of timber bears a definite relation to the size of tree and that the price for thinnings is about three-quarters of that of

a main crop with the same average-sized tree. The size-price relationship which has been adopted as a basis is that used for Scots pine in *Oxford Forestry Memoir*, No. 6,[1] which is shown in Fig. 1. Owing to the method of work-

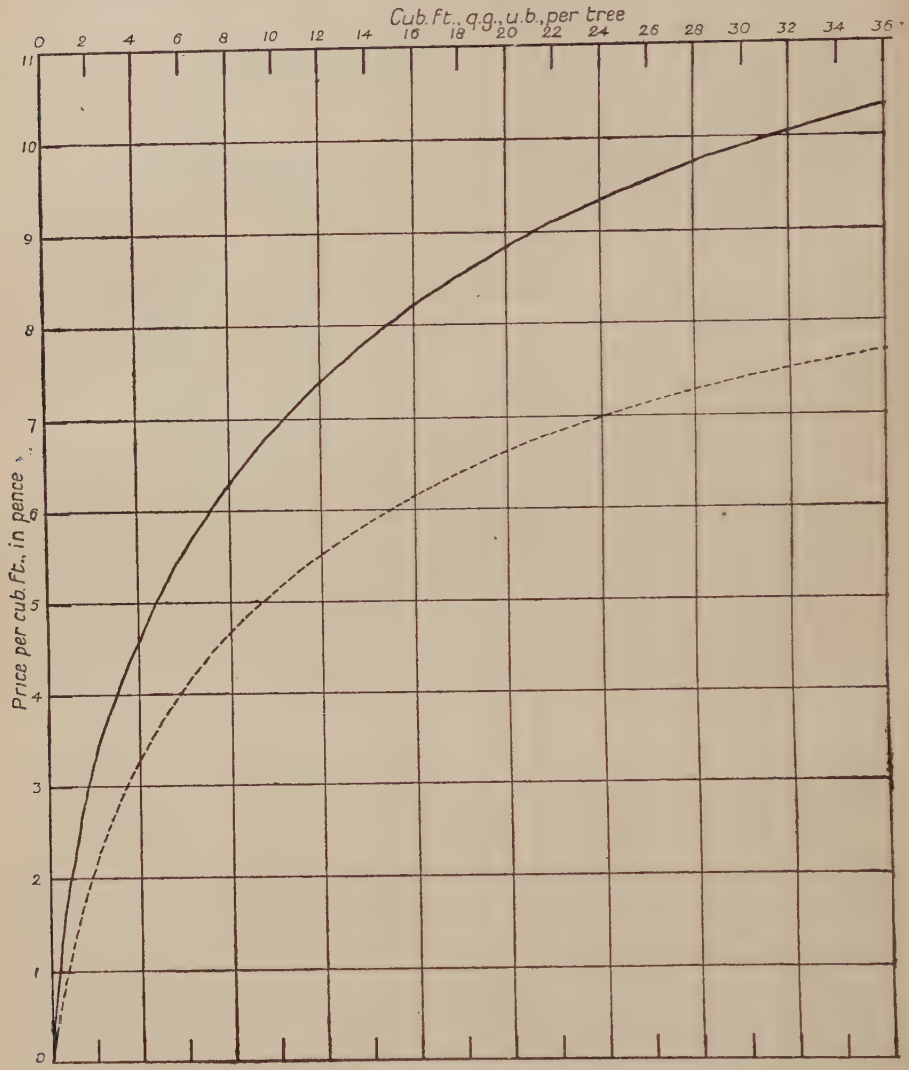

FIG. 1

ing, the actual prices shown in this graph are of no significance; what is retained is the relationship between the price at any size and the price of all previous thinnings. This point will become clearer by an example of the method adopted.

Calculations are based on money yield tables. Such a yield table is shown in Table I for Norway spruce, Quality I. The number of trees and volume of

[1] W. E. Hiley, 'Financial return from the cultivation of Scots pine and Corsican pine', *Oxford Forestry Memoir*, No. 6, 1926.

TABLE I. *Money Yield Table for Norway spruce, Quality I, with Scots pine Standard Prices*

AGE.	MAIN CROP.						THINNINGS.					FINAL YIELD VALUE.
Years	*No. of stems per acre*	*Vol. cu. ft.*	*Vol. per tree. cu. ft.*	*Price per cu. ft. d.*	*Value per acre. £*	*Value less 30% £*	*No. of stems per acre*	*Vol. cu. ft.*	*Vol. per tree. cu. ft.*	*Price per cu. ft. d.*	*Value per ac. Yr. £*	*Yr. £*
25	1,080	2,400	2·2	3·3	33·0	23·1	—	—	—	—	—	—
30	710	3,500	4·9	5·1	74·4	52·0	370	410	1·1	1·4	2·4	54·4
35	535	4,400	8·2	6·3	115·5	80·8	175	440	2·5	2·3	4·2	85·0
40	410	5,250	12·8	7·5	164	115	125	485	3·9	3·1	6·3	121
45	335	6,030	18·0	8·5	214	150	75	490	6·5	4·2	8·6	159
50	280	6,760	24·1	9·3	262	183	55	470	8·5	4·8	9·4	192
55	240	7,420	30·9	10·0	309	216	40	445	11·1	5·3	9·8	226
60	210	8,020	38·2	10·5	351	246	30	415	13·8	5·8	10·0	256
65	190	8,530	44·9	10·7	380	266	20	345	17·2	6·3	9·0	275
70	175	8,960	51·2	11·0	410	287	15	320	21·3	6·7	8·9	296

the main crop are taken from the British Yield Tables,[1] and the average size of the tree at each age is calculated. The price per cubic foot is read off from the Scots pine price-size gradient, and the value of the main crop is determined by multiplying the volume by the price per cubic foot. It is assumed that 70 per cent. efficiency is attained, so that this value must be reduced by 30 per cent. The value of the thinnings is obtained in exactly the same manner, except that full efficiency is assumed since some of the accidents which reduce the value of the main crop (e.g. windfalls) actually increase the value of the thinnings. The value of the final yield is obtained by adding the value of the main crop to the value of the thinning at each age.

It is next necessary to take some values for the price of land, cost of planting, and cost of annual management. Table II shows the amounts that have been inserted for these costs. The cost of land should include the cost of clearing scrub and any draining which need not be repeated in a subsequent rotation. The cost of planting includes fencing, plants, and planting, but not beating up, weeding, or overheads. The prices are rather lower than can generally obtain on private estates, but are fairly normal for the Forestry Commission.

The cost of annual management includes all overheads (less the value of sporting rents) and costs of general upkeep. It also includes the cost of cleaning and beating up in the early years, unremunerative thinnings in early middle life, and rides which become necessary for extraction at the end of the rotation. It is assumed that these costs are constant throughout the rotation, though in practice this may not be the case; but the inclusion of the cost of beating up and cleaning in maintenance rather than planting helps to equalize out the cost of annual management. The cost of management is higher for some situations and some species than for others; less beating up will be required for

[1] *Forestry Commission Bulletin*, No. 10, 1928.

TABLE II. *Price of land, cost of planting, and cost of annual maintenance per acre*

Species.	*Quality Class.*	*Price of land.* S £	*Cost of planting.* C £	*Annual maintenance.* e s.
Scots pine	I	3	5	12 or 8
	II	2	5	,,
	III	1	5	,,
Corsican pine	I	3	7	12 or 8
	II	2	7	,,
	III	1	7	,,
Norway spruce	I	6	7	12 or 8
	III	4	7	,,
	V	2	7	,,
Sitka spruce	I	6	8	12 or 8
	III	4	8	,,
	IV	3	8	,,
European larch	I	6	10	12 or 8
	III	4	10	,,
	V	2	10	,,
Douglas fir	I	7	9	12 or 8
	III	4	9	,,
	IV	3	9	,,
Oak	I	6	12	20 or 10
	III	2	12	,,

Scots pine than for larch. On the other hand, there may be no unremunerative thinnings with larch, whereas with Scots pine they can scarcely be avoided. Also fire protection is more expensive on dry pine soils than on wet spruce soils. However, the same cost of maintenance has been used for each species, with the exception of oak, as it is very difficult to distinguish between them. It is difficult to say whether the cost of maintenance is likely to be higher or lower on the Forestry Commission areas than it is on private estates; in the former case overhead charges will almost certainly be more severe, but this will be largely compensated for by the greater ease of managing large areas.

The following example refers to Norway spruce, Quality I, on a rotation of 55 years, at which the average size of tree is 30·9 cubic feet. The equation on which it is based is the well-known Faustmann equation:

$$S = \frac{\Upsilon r + \Sigma \mathcal{T} a \,.\, 1 \,.\, op^{r-a} - C \,.\, 1 \,.\, op^{r}}{1 \,.\, op^{r} - 1} - \frac{e}{0{\cdot}op}.$$

This may be written $S = X - Z$,

$$\text{where } X = \Upsilon r \left(\frac{1}{1 \,.\, op^{r} - 1}\right) + \mathcal{T} a \left(\frac{1 \,.\, op^{r-a}}{1 \,.\, op^{r} - 1}\right) + \ldots$$

$$\text{and } Z = C \,.\, \left(\frac{1 \,.\, op^{r}}{1 \,.\, op^{r} - 1}\right) + e \,.\, \left(\frac{1}{0{\cdot}op}\right).$$

The amount summed up under X is determined by the values of main crop and thinnings each multiplied by its appropriate factor; the amount Z is the sum of the costs of planting and management again multiplied by their appropriate factors.

		3%		4%		5%	
Final Yield.	£	*Multiplier.*	£	*Multiplier.*	£	*Multiplier.*	£
Y_{55}	226	0·2450	55·4	0·1308	29·6	0·0733	16·6
Thinnings.							
T_{30}	2·4	0·513	1·2	0·349	0·8	0·248	0·6
T_{35}	4·2	0·442	1·9	0·287	1·2	0·195	0·8
T_{40}	6·3	0·382	2·4	0·235	1·5	0·152	1·0
T_{45}	8·6	0·329	2·8	0·194	1·7	0·119	1·0
T_{50}	9·4	0·284	2·7	0·159	1·5	0·094	0·9
X			66·4 (34·7)		36·3 (28·9)		20·9 (25·5)
C	7·0	1·24	8·7	1·13	7·9	1·07	7·5
e	0·6	33·3	20·0	25·0	15·0	20·0	12·0
Z			28·7		22·9		19·5
$S = X - Z$			37·7 (6)		13·4 (6)		1·4 (6)

This calculation shows that if land were bought for £13·4 per acre and treated in this manner, exactly 4 per cent. would be realized. If, however, land were paid for at the rate of £6 (see Table II) per acre the total value of X need only be £28·9 to yield 4 per cent. Thus the price of the final yield and all thinnings might have been $\frac{28·9}{36·3}$, i.e. 0·796 times the prices which were used in the calculation. Actually the price taken for trees of this size (30·9 cu. ft.) was 10·0*d.*, so that to earn 4 per cent. it would have been sufficient if the price had been 8·0*d.*, and this figure may be regarded as the cost of producing spruce of this size on Quality I sites costing £6 per acre if 4 per cent. is charged to capital.

In the same manner a tree of 12·8 cubic feet should be produced on a 40-year rotation at a cost of 6·6*d.* and a tree of 8·2 cubic feet on a 35-year rotation at a cost of 6·4*d.* per cubic foot. Combining these values by a graph it appears that the cost of producing a 10 cubic foot tree is 6·5*d.*, a 20 cubic foot tree is 7·0*d.*, and a 30 cubic foot tree 7·9*d.*

Calculations have been made in this manner for Scots pine, Corsican pine,[1] Norway spruce, Sitka spruce, and Douglas fir, and the results are shown in Table III. Larch had to be treated in a special manner as the cost of production of larch timber is greatly reduced by the high price which can be obtained for thinnings. This price varies greatly from place to place, and in these

[1] The volume of thinnings for Corsican pine has been taken from *Oxford Forestry Memoir*, No. 6, 1926, as calculations are here used which were made for that memoir before the British Yield Tables of 1928 were published.

TABLE III. *Costs of production per cubic foot*

Species.	*Quality class.*	*Size of tree. cu. ft.*	*Price per cubic foot required to earn* 3% e=12s. s. d.	3% e=8s. s. d.	4% e=12s. s. d.	4% e=8s. s. d.	5% e=12s. s. d.	5% e=8s. s. d.
Scots pine	I	10	8·7	6·7	1 1·0	10·3	1 7·3	1 3·6
		20	11·4	8·7	1 7·6	1 2·7	2 8	2 1
		30	1 2·8	11·1	2 2·4	1 10·4	4 1	3 4
	II	10	11·6	8·8	1 6·3	11·8	2 5	1 4·6
		20	1 4·0	1 0·1	2 4·4	1 9·5	4 4	3 7
		30	1 10·3	1 4·9	3 8	2 10	7 6	5 11
	III	10	1 5·4	1 1·2	2 10	1 10·2	4 2	3 3
		20	2 2·4	1 7·8	4 3	3 3	9 3	7 3
Corsican pine	I	10	4·8	3·8	6·3	5·1	8·6	7·0
		20	5·6	4·3	8·2	6·3	11·7	9·4
	II	10	6·5	5·0	9·2	7·2	1 1·0	10·4
Norway spruce	I	10	4·8	3·9	6·5	5·5	8·8	7·5
		20	4·9	4·0	7·0	5·9	10·3	8·7
		30	5·1	4·2	7·9	6·5	1 0·0	10·1
	III	10	7·2	5·7	10·4	8·5	1 3·1	1 0·5
		20	8·3	6·6	1 1·2	10·6	1 9·6	1 5·8
		30	9·9	7·7	1 4·8	1 1·7	2 5·0	1 11·9
	V	10	1 2·5	11·2	2 0·0	1 7·1	3 5·5	2 10
Sitka spruce	I	10	2·9	2·5	3·8	3·3	4·9	4·2
		20	3·1	2·6	4·1	3·5	5·7	4·7
		30	3·3	2·7	4·6	3·8	6·5	5·4
	III	10	4·3	3·5	5·6	4·7	7·5	6·3
		20	4·5	3·6	6·3	5·1	8·8	7·4
		30	4·7	3·8	7·0	5·8	10·5	8·9
	IV	10	5·6	4·6	7·5	6·2	10·4	8·7
		20	5·9	4·8	8·7	7·1	1 1·0	11·0
Douglas fir	I	10	3·6	3·1	4·5	3·9	6·0	5·0
		20	3·5	3·0	4·8	4·0	6·3	5·3
		30	3·7	3·1	5·1	4·2	6·7	5·9
	III	10	4·3	3·6	5·7	4·8	7·3	6·3
		20	4·7	3·9	6·5	5·4	8·9	7·5
		30	5·0	4·1	7·1	5·9	10·1	8·5
	IV	10	5·5	4·6	7·2	6·0	9·7	8·2
		20	5·8	4·7	7·9	6·5	11·1	9·3
		30	5·8	4·6	8·5	7·0	1 0·3	10·3
European larch	I	10	6·0	5·0	8·0	6·8	10·7	9·3
		20	7·0	5·8	8·3	8·7	1 2·7	1 0·8
		30	8·3	6·9	1 0·9	10·9	1 7·3	1 4·6
	III	10	10·6	8·7	1 3·5	1 1·1	1 10	1 7·2
		20	1 2·2	11·4	1 10·0	1 7·7	2 10	2 5·4
	V	10	2 1	1 8·2	3 8	2 11	5 10	4 11
			e=20s.	e=10s.	e=20s.	e=10s.	e=20s.	e=10s.
Oak	I	10	2 0	1 5	3 1	2 3	4 10	3 7
		20	2 1	1 5	3 6	2 6	5 10	4 4
		30	2 3	1 7	4 0	2 10	7 2	5 4
	III	10	4 7	3 0	8 7	5 10	16 1	11 4
		20	5 11	3 11	12 2	8 3	23 0	16 7
		30	7 8	5 0	15 9	10 8	30 0	21 0

calculations it has been assumed that, corresponding to a price of 1*s.* 4*d.* per cubic foot for a tree of 20 cubic feet, thinnings have been sold for 2*d.* each at 15 feet high (total height), 3*d.* at 25 feet, 4½*d.* at 35 feet, and 6*d.* at 45 feet. Where, as happens not infrequently, the thinnings can be sold for 3 or 4 times these prices the cost of production of timber trees will be much lower.

Table III contains so many figures that it is rather confusing. The costs per cubic foot of the trees of 20 cubic feet at 4 per cent. compound interest have therefore been picked out and are given in Table IV. From these tables the following conclusions may be drawn:

TABLE IV. *Cost per cubic foot of producing trees of* 20 *cubic feet at* 4 *per cent. interest* (*cost of annual management* 12*s. per acre for conifers and* 20*s. for oak*)

Quality of site.	*Scots pine.*	*Corsican pine.*	*Norway spruce.*	*Sitka spruce.*	*Douglas fir.*	*European larch.*	*Oak.*
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Good . .	1 7¾	8¾	7	4	4¾	8¾	3 6
Intermediate	2 4¾	—	1 1¾	6¾	6¾	1 10	—
Poor . .	4 3	—	—	8¾	8	3 8	12 2

1. The cost of producing timber is much less on good than on poor quality land even when the cost of the land is taken into account. In other words, the market price of land is not proportional to its value as a basis of cultivation. The same generalization has been observed in the case of agriculture, and it appears to be applicable over a wide range of cultivation. It follows from this that in order to produce as cheaply as possible it is necessary to select the best possible sites. But foresters are generally debarred from using land which has an appreciable agricultural value and are therefore confined to the cheaper soils. In Britain, however, there are two ways of countering this handicap:

(i) Many old woodlands have a very good forest soil; owing to the cost of clearing, these areas may be expensive to plant, but, despite this, timber may be produced more cheaply on them than on soils which are bare because they are very poor.

(ii) Poor soils may be improved by various means such as draining, ploughing, subsoil ploughing, manuring, and the cultivation of green manuring crops. The technique of soil improvement is as yet in a very undeveloped state, but the large, continuous areas which are being planted up to-day should give scope for the use of high-power machinery, and there should here be an opening for the profitable use of a large amount of labour. The view is not infrequently advanced that, when planting up very poor land, a 5th quality stand may be tolerated on the ground that subsequent rotations are likely to be better. The figures in the table suggest, however, that a 5th quality stand is a very costly form of cultivation, and direct methods of improving land may ultimately prove to be very much cheaper.

2. The various species differ greatly in their cost of production. Sitka spruce and Douglas fir are by far the cheapest to produce and, since Sitka spruce-thinnings may under favourable circumstances be used for pulp and Douglas fir for many of the uses to which larch is at present put, the costs of production will probably prove to be lower than those shown in the table.

Sitka spruce costs about one-half to one-third as much as Norway spruce and, since the timbers appear to be of equal value and the species require similar conditions in Britain, it may be questioned whether Norway spruce should ever be grown.

Corsican pine bears about the same relation to Scots pine as Sitka spruce bears to Norway spruce, but it appears that the timber of Scots pine is definitely superior to that of Corsican. It is worth while to make a very great effort to grow Douglas fir rather than Scots pine, and a 4th quality Douglas fir plantation is likely to be more remunerative than a 1st quality Scots pine plantation. The ease of establishing Scots pine is a facile snare for the uninitiated, and it is only the uneconomic forester who will regard a Scots pine plantation as satisfactory on land that could have been made to grow more profitable species.

The cost of growing European larch is very greatly influenced by the price at which thinnings can be sold, and too much weight must not be attached to the costs of production given in the table. As a ready market can always be found for this timber, generally at very favourable prices, larch must be considered one of the most profitable conifers to grow.

The cost of production of oak is based on Qualities I and III of Schwappach's volume yield table for Prussia.[1] The rate of growth represented by Quality I is about equal to that of Quality II of Wimmenauer's Table which was converted into English measure by Schlich in Volume III of his manual, and it represents a total growth of 9,095 cubic feet, q.g., per acre in 100 years. This is probably equivalent to the best growth in Britain. Schwappach's Quality III shows a total growth in 100 years of 5,100 cubic feet, q.g., of which half is removed as thinnings. Quality I takes 85 years and Quality III 135 years to produce an average tree of 30 cubic feet.

In reading the calculated costs of production from the tables it should be remembered that a high cost of production presupposes a proportionately high sale price for thinnings and a low cost of production a proportionately low sale price for thinnings. Thus, when it is shown that on Quality III sites oak of 20 cubic feet costs 12*s.* 2*d.* per cubic foot to produce, this presupposes that thinnings of 5 cubic feet can be sold for 5*s.* per cubic foot; whereas production of Sitka spruce on Quality I sites is possible at 4*d.* per cubic foot if thinnings of 5 cubic feet fetch only 1¾*d.* per cubic foot. This system of proportional prices has been adopted because it is less objectionable than assuming fixed prices for thinnings, since no fixed prices would be of general application. If, however, actual prices were inserted for thinnings the cost of production

[1] *Untersuchungen über die Zuwachsleistungen von Eichen-Hochwaldbeständen in Preussen*, Neudamm, 1905.

of Sitka spruce and Douglas fir should be lower, and that of Scots pine and oak higher than the figures given in the tables.

The results of these calculations are distinctly encouraging to British forestry, and it appears that, if good management is assured, a return of 4 per cent. may be expected, on an average, from capital invested in planting, and higher rates of interest in favourable localities. As this return is very nearly free of income-tax and super-tax the investment may be considered attractive from the point of view of the private landowner.

THE MULTIPLE MYCORRHIZAS OF TREES

BY M. C. RAYNER, D.Sc.

THE regular and intimate association of fungus mycelium with roots of vascular plants to form the composite structures called 'fungus-roots', or mycorrhizas, has engaged the attention of botanists since Frank first described it clearly in 1885. From the first, speculation was busy as to the effects produced upon the host. Theories attributing a beneficial rôle to the root-fungi soon appeared, but the lack of experimental evidence deduced from the behaviour of individual plants of the same species with and without mycorrhiza challenged criticism and left the practical issue clouded by controversy.

The opening years of the present century saw the application of novel and effective experimental methods to mycorrhiza problems, and there is now in existence a large body of trustworthy evidence respecting the rôle of mycorrhiza in vascular plants. Such interest as is shown in the subject by the practical grower—agriculturist, horticulturist, or forester—is comparatively recent and springs directly from his preoccupation with the effects produced upon crop yield by the presence of mycorrhiza and the possibility of modifying these effects by cultural methods.

Although the subject is still virtually ignored in British text-books dealing with soil problems in relation to husbandry, signs are not lacking that, in respect to the cultivation of certain crop plants—legumes in America, strawberries in this country, sugar-cane and possibly other tropical crops—the control of mycorrhiza formation may become a matter of urgent importance. To orchid growers the experimental discoveries of Bernard, supplemented subsequently by those of other observers, have long been a matter of practical concern.

Historically, the mycorrhiza of forest trees was the first to attract general attention, and foresters have been quick to appreciate the significant results obtained in this field by modern experimental methods. The main purpose of the present article is to summarize these results as briefly as possible and give some indication of their bearing on practical silviculture.

What are the known facts?

Mycorrhiza is formed habitually by both coniferous and deciduous trees and is most characteristically developed in woodland soils of the more acid type, especially in the well-aerated surface layers of such soils, where fungus-roots may often be found embedded only in the superficial covering of partially decomposed leaves.

Its formation is periodic, coinciding with the period of maximum root development, usually annual, although this is subject to variation, and commonly affects a large proportion of the young absorbing roots of the current year.

The mycorrhizas of trees are shorter and thicker than normal rootlets; some are simple and unbranched, but often arrest of growth is accompanied by profuse branching, resulting in dense clusters of forked rootlets, sometimes so crowded as to appear like small tubers. Webs of mycelium are often conspicuous in the surrounding soil, and the fungus-roots themselves are frequently coloured in various ways according to the character of the mycelium present. In general, their structure is of the type originally described as *ectotrophic*, but there is less uniformity and more extensive invasion of the root-cells than was formerly believed, and the term *ectendotrophic*, i.e. combining the characters of ecto- and endotrophic, more correctly describes the structure of many of them (5).

The check to growth and stimulation of branching are related directly to the formation of a sheath of interwoven hyphae about the tip and growing region of the young roots. Outwardly, this mycelial envelope may present a smooth continuous surface or appear rough from the more or less profuse development of outward-growing hyphae; inwardly, its constituent hyphae send off branches which penetrate freely between the cortical cells and give rise to a characteristic network which force their way into the cells of the external layer, and—to an extent much greater than was formerly believed—also into those of the underlying tissues.

The formation of this enveloping sheath usually sets a limit to elongation of the individual root, but cases have been observed in which renewed growth carries the root clear of the investing web of mycelium, so initiating a fresh cycle of activity (3). Much interest attaches to the fate of the hyphae that invade the living cells of the root: in healthy and functional tree mycorrhiza they commonly disintegrate, following upon a digestive action by the root-cells, and their condition in this respect may afford valuable information as to the response shown by the roots to fungus infection and the health or otherwise of the trees.

Although of historical interest to students of mycorrhiza, the older theories of beneficial symbiosis need not detain us, since all such were deduced almost exclusively from structural features unconfirmed by satisfactory experimental evidence. Indeed, such evidence is singularly difficult to obtain, involving the isolation and identification of the root-fungus or fungi, the maintenance of both symbionts in 'pure culture' uncontaminated by other organisms, and, finally, the study of comparative cultures of the host tree with and without mycorrhiza. Sound conclusions respecting the rôle of mycorrhiza in the life of the higher plants must rest securely upon experimental evidence. In the case of trees, a sharp distinction must be drawn between evidence deduced from the proximity of certain toadstools to particular trees and (or) attempts to trace continuity of the associated mycelium with that in individual mycorrhizas, and that based on critical experiments involving the use of pure cultures.

We owe the foundations and much of the superstructure of exact experimental knowledge respecting the rôle of mycorrhiza in trees to a Swedish botanist and

forester, Dr. Elias Melin (4, 5, and 6) of Stockholm, to whose observations in Europe have recently been added those of Masui (3) in Japan. Certain facts are well established. In Sweden a number of fungi common in woods have been identified as specific mycorrhiza-formers of pine, spruce, and other trees. These belong to saprophytic genera, and there is no evidence of parasitism of the ordinary kind. They show specialization to the symbiotic habit; and it is possible, although not finally proven, that some of them are obligate symbionts unable to complete their development, except in association with roots of their hosts. Neither true parasites or true saprophytes physiologically, the name 'symbiophiles' has been suggested for them (5). There is conclusive evidence that normal mycorrhiza is developed only in a suitable rooting medium; its formation in trees is marked by sensitiveness to changes of reaction in the soil, to the presence of unsuitable nutrients and to toxic substances such as those produced by heat sterilization, but there is no indication that the early stages of seedling growth are bound up in any way with infection. In general, mycorrhiza formation by trees appears to be a reciprocal phenomenon conditioned in a very marked degree by the physiological state of both symbionts.

With respect to nutrition, the evidence deduced from laboratory experiments indicates that absorption of mineral salts in raw humus soil is carried on more efficiently by infected than by uninfected roots. The most significant results, however, relate to nitrogen metabolism.

There is at present no evidence for fixation of atmospheric nitrogen by any of the known root-fungi of trees. On the other hand, it has been shown that seedlings provided with mycorrhiza utilize organic compounds of nitrogen such as are present in acid humus to better advantage than do those lacking fungus infection. Since the supply of nitrates is often deficient in woodland soils, Melin's conclusion that mycorrhiza possesses a vital significance for trees and other plants growing in raw humus soils is doubtless fully justified. In Northern Europe tree mycorrhiza is typically developed under such conditions, and there is good reason to believe that the soil reaction and the character of the organic compounds present are important factors in promoting its healthy development and functioning.

It is of interest to note that these conclusions are supported by Falck's observations on the nutritive significance of mycorrhiza in acid woodland soils in Germany. There can be little doubt that further experiments will justify their extension to all trees growing in such soils and possessing a similar mycorrhizal habit.

In one respect in particular, the fungus-roots of trees differ remarkably from those of other mycotrophic plants, e.g. Orchids and Heaths. They are *multiple mycorrhizas* formed by the association and interaction of several fungus associates. This fact at once complicates the symbiotic relation and raises many points of interest concerning the maintenance of a balance of power, not only between root and mycelium but among the individual fungi present, with possible reactions on the part of the host to disturbance of such balance. It is certain that mycelium of several fungi may be present simultaneously and that

different types of mycorrhiza representing such individual symbionts may develop side by side upon the same main root. Whether more than one fungus can be present in a single mycorrhiza is less certain. It is unlikely that this possibility is excluded, although probably of relatively infrequent occurrence.

Before going on to consider the bearing of these matters on practical problems, it may be of interest to summarize what is known respecting the identity of the root-fungi of trees, in so far as this has been tested and proved by experimental methods.

In Northern Europe the fruit bodies of many fungi, especially Hymenomycetes, are a constant and conspicuous feature of most woodlands in favourable weather, and in many cases other than the classical one of truffles these are habitually associated with particular tree species—'that the kind of tree has something to do with it, nobody can doubt who has seen *Cortinarius hemitrichus* follow the birch as the dolphin follows the ship' (2). From their distribution alone, supported by attempts to trace continuity of the mycelium associated with individual toadstools with that in the root sheaths, many of the fungi to which these fruit bodies belong had already been cited as mycorrhiza-formers before Melin's experimental researches confirmed certain of the attributions and placed the following facts beyond doubt (5).

As might be expected, the majority of *proved* mycorrhiza-formers are Hymenomycetes: species of *Boletus*, *Amanita*, *Cortinarius*, *Lactarius*, *Russula*, and *Tricholoma* have already been identified, and other genera will doubtless be added to this list as time goes on. In spite of the prevalence of some Gasteromycetes, e.g. the Common Puffball (*Scleroderma vulgare*), beneath certain trees, no member of this group has yet been identified with certainty in Europe as a root-fungus, nor, among Ascomycetes, is proof yet available that either of the fungi whose proximity to tree roots was responsible both for the original discovery of fungus infection in tree roots and for the name *mycorrhiza* bestowed upon it, i.e. the Truffle (*Tuber* sp.) and the False Truffle (*Elaphomyces*, sp.), are actually mycorrhiza-formers.

For certain trees the necessary experimental proof has now been supplied by isolation and cultivation of the symbionts with subsequent formation of mycorrhiza under 'pure culture' conditions. Thus, for the Scots pine (*Pinus silvestris*) are known *Boletus badius*, *B. variegatus*, *Amanita muscaria*, *Cortinarius mucosus*, *Lactarius deliciosus*, *Russula fragilis*, with a series of forms included under the name *Mycelium radicis silvestris*, α, β, γ, δ, of which those belonging to the α group have already been identified as species of *Boletus* common in pine woods, viz. *B. granulatus*, *B. variegatus*, *B. luteus*, *B. badius*, and possibly *B. bovinus*. For mountain pine (*P. montana*), are known *Boletus granulatus*, *B. variegatus*, *Cortinarius mucosus*, *Lactarius deliciosus*, *Russula fragilis*, *Tricholoma virgatum*, together with the forms included under *Mycelium radicis silvestris*, α, β, γ. For the spruce (*Picea abies*), *Boletus luteus* (probably) with *Mycelium radicis silvestris*, α, β, γ, and a corresponding form specially associated with spruce, *Mycelium radicis Abietis*. For larch (*Larix*

europaea and *L. occidentalis*), *Boletus elegans*, *B. luteus*, *B. variegatus*, *Amanita muscaria*, *Cortinarius camphoratus*, *Tricholoma psamnapus* with *Mycelium radicis silvestris*, α, β. For birch (*Betula alba* and *B. pendula*), *Boletus edulis*, *B. rufus*, *B. scaber*, *Amanita muscaria*, *Cortinarius camphoratus*, *Tricholoma flavobrunneum*, and *Mycelium radicis silvestris*, γ. For aspen (*Populus tremula*), *Boletus rufus* and *B. scaber* (5).

In Japan the researches of Masui (3) have added to this list the following: for *Pinus densiflora*, *Armillaria caligata*, *A. Matsudakse*, *Boletus bovinus* and *Tricholoma Shimeji*; with possibly *Boletus luteus* for *Pinus Thunbergii* and a number of species of *Quercus*. From the close association of spore bodies with the mycorrhizas concerned, Masui infers that certain of these fungi are *obligate* symbionts unable to complete their life cycle except in association with roots; others are facultative mycorrhiza-formers capable of independent development.

In respect to the rôle of mycorrhiza in the trees investigated, Masui reaches conclusions very different from those of Melin just cited, holding that the obligate forms are parasites filching from the roots practically all their required nutrients, while the facultative forms are responsible for more or less mutualistic relations, supplying phosphates and other salts to their hosts in exchange for organic materials abstracted from the roots. The experimental evidence on which this worker relies, cannot, however, be regarded as conclusive. Moreover, Melin's observations on the natural conditions favourable or otherwise to normal mycorrhiza formation have an important bearing on Masui's conclusions.

Melin recognizes the existence of fungus-roots described as *pseudomycorrhizas*, in which the intimate structure provides evidence of one-sided parasitism on the part of the invading mycelium. These are due to the entry of fungi markedly different in type from those responsible for true mycorrhiza, and may be regarded as an indication of soil conditions unfavourable to its formation. In Sweden pseudomycorrhizas have been noted as especially common on wet moorland soils recently drained. From such observations emerges the general conclusion that the formation of healthy and typical mycorrhiza by any tree depends upon a complicated series of reciprocal reactions conditioned by the physiological states of both roots and mycelium. For the accomplishment of a true mutualistic relation, propinquity of the appropriate fungus or fungi is not enough. Invasion of the roots by mycelium must take place under conditions favourable to its establishment, the exact character of such conditions in nature offering a field for research as yet practically unexplored. Mycorrhizas resembling those found in nature have been obtained in experimental cultures, but their comparative rarity is a measure of the ignorance still prevailing as to the precise soil conditions that control their profuse development under natural conditions.

It is in respect to these aspects of the problem that it has become a matter of practical importance to foresters to learn how best to control the soil conditions favourable or otherwise to the free development of the right kind

of mycorrhiza, and determine to what extent this knowledge can be applied to practical silviculture, for example, to the afforestation of new areas.

Observations in the field lend support to these theoretical conclusions. For example, Steven (8) has noted the behaviour of young Norway spruces upon certain soils unfavourable to growth and apparently also inimical to mycorrhiza formation, emergence from check coinciding with changes in the surface herbage favourable to more efficient aeration and, incidentally, to the free development of fungus-roots. A causal relation between the two sets of phenomenon is not definitely proved, but even lacking this the value of mycorrhiza as an indicator of optimum growth conditions for spruce is sufficiently obvious.

Even more striking is evidence gleaned from the recent researches of Hesselman (1) and Melin (6) in Sweden. Hesselman's experiments show that certain types of humus are much more beneficial than others to the growth of seedling pines. In sand mixed with such favourable humus, seedlings grew faster, were more vigorous, and formed a markedly better root-system in which the free development of mycorrhiza was a conspicuous feature. Experimental evidence pointed to the latter as an independent factor in promoting vigorous growth and led to a detailed study by Melin of the root-systems of the experimental seedlings. The resulting observations are of much theoretical interest in relation to the very complicated conditions in nature that favour the formation of mycorrhiza of a type beneficial to the trees concerned, and are of great practical importance in respect to the growth of young trees in new plantations. They lead inevitably to the conclusion that the types of humus soil most favourable to the growth of seedling pines promote likewise an easy and profuse development of mycorrhiza of the true mutualistic type. Under adverse soil conditions, true mycorrhiza is formed with greater difficulty and replaced more or less completely by various types of pseudomycorrhiza caused by the entry of fungi which show a tendency to one-sided parasitism. Moreover, the rapid formation of true mycorrhiza in favourable soils impedes the entry of the latter and thus benefits the trees not only *directly* by a beneficial effect upon nutrition, but also *indirectly* by protecting them from invasion by mycelium likely to inflict injury upon the roots.

It would be difficult to find a more encouraging example of the direct application of experimental research to field conditions. The immediate need is for more work on similar lines directed to learn the best means of promoting favourable humus conditions and encouraging those fungi most effective in establishing beneficial symbiosis, work clearly involving the close co-operation of the forester with the trained laboratory worker.

REFERENCES

(1) Hesselman, H.: 'Studien ü. die Entwicklung der Nadelbaumpflanze in Rohhumus', I. *Meddel. f. Stat. Skogsförsöksanst.*, 23, 1927, p. 337.

(2) Lange, J. E.: 'Studies on the Agarics of Denmark'. *Dansk Bot. Ark.* 4, 1923, p. 2.

(3) Masui, Koki: 'A Study of the ectotrophic Mycorrhizas of woody plants'. *Mem. Coll. Sc.*, Kyoto Imp. Univ., Ser. B., 3, 1927, p. 149.

(4) Melin, Elias: 'Experimentelle Untersuchungen ü. die Konstitution u. Ökologie d. Mykorrhiza v. *P. silvestris*, L., u. *Picea Abies*, Karst.' *Mykol. Untersuch. u. Ber. v. R. Falck*, 2. Cassel, 1923.

(5) —— *Untersuchungen ü. die Bedeutung der Baummykorrhiza*, Jena, 1925.

(6) —— 'Die Ausbildung der Mykorrhiza bei der Kieferpflanze in verschiedenen Rohhumusformen.' *Meddel. f. Stat. Skogsförsöksanst.*, 23, 1927, p. 433 (see also Hesselman).

(7) Rayner, M. C.: *Mycorrhiza*. Wheldon & Wesley, Ltd., London, 1927.

(8) Steven, H. M.: 'Silviculture of Conifers in Great Britain.' *Forestry*, vol. i, No. 1, 1927, p. 18.

WASTE LANDS OF NORTH WALES

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IN any attempt to decide as to the relative advantages of sheep farming and afforestation it is important to know the characteristics of the soil and climate of the disputed area. Obviously there are some types of land which the forester would scarcely wish to wrest from the sheep farmer. Other tracts may be highly eligible for the forester, but are of such value for pasturage that they could not be economically diverted from their present use. Indeed, it is not an exaggeration to say that, so far as upland grazing is concerned, the more valuable the grazing, the more desirable it is for the purpose of tree planting, provided the shelter be adequate.

I shall attempt in the present paper to describe some of the principal types of uncultivated land in North Wales. Many of the types are probably common to other mountainous and hilly regions and their description may thus be of more than purely local interest. In the first place, however, it may be allowable to make some conjectures as to the past history of the soils of our area.

In prehistoric times North Wales was probably covered with deciduous forest up to about 1,700 feet above sea-level. The only areas free from forest were the swamps and marshes, the dune areas, and exposed coastal headlands. It seems likely that, as a consequence of deforestation and cultivation, wholesale erosion must have taken place, resulting, in many situations, in the almost complete removal of soil and subsoil, or, in less erodable areas, in the removal of the surface soil and the exposure of the subsoil. Large areas of soil in North Wales have the characters of a primitive subsoil. The original soil was partly washed away into the rivers and partly deposited in hollows which are to-day wet rushy bottoms of greyish soil, sometimes carrying a cover of peat. In time, the present system of grass husbandry with grazing was established. This led to the enrichment of the soil in organic matter and consequent protection against further erosion. It appears, therefore, that the soils of our area have been considerably modified from their primitive condition, but are now more or less stabilized owing to the prevalence of the artificial steppe conditions induced by grazing husbandry. It is, perhaps, worthy of mention that a process similar to that which has been suggested in the past for North Wales appears to be going on in parts of the eastern regions of the United States. There, wholesale deforestation has led to intense erosion, which is still in progress and which seems likely to modify considerably the primitive soil types. The establishment of artificial steppe conditions for the purpose of grazing might arrest the erosion and produce conditions similar to those in North Wales.

Before describing the principal types of uncultivated lands it may be well

to allude briefly to the character of the soil-forming processes in the area. The principal factors in soil-profile development in our area are (1) the climate, which is extremely humid and leads to intensive leaching of the soil horizons; and (2) the parent rocks, which are generally ancient sedimentary, igneous, or metamorphic rocks, considerably indurated and free from calcium carbonate. These conditions result in a profile in which the clay-humus complex is of a base-unsaturated or acid character throughout, and in which the superficial or A horizons tend to be bleached owing to removal of sesquioxides, which are accumulated in the underlying B horizons. Owing to past erosion, mature profiles are not common. Such profiles as are found may be secondary profiles developed in what was originally the B horizon of the original profile. Owing to the generally hard character of the parent rocks, upland profiles are rather shallow.

From the point of view of possible afforestation the soils of the heath series are probably the most eligible. I shall therefore mention these in the first place, and discuss them in greater detail than the other types, which are characterized by impeded drainage, high water table, or other circumstances which must depress their value from the forester's standpoint. The heaths form a series varying from the grass heaths, to which some of the land actually under cultivation properly belongs, to the poorest heather moorland. Heath is essentially a dry formation. Naturally in such a wet climate as that of North Wales heath soils are frequently very wet, but they are of such a character that a drought of even a few weeks in summer leads to conditions under which only plants of markedly xerophilous character can survive. The heaths in our area are also characterized by soil acidity, which becomes the more pronounced as the heath character is developed. The xerophytic character of certain plants on normally wet soils may be connected with the fact that such soils periodically suffer from extreme physiological drought.

Grass Heath. This type, broadly speaking, lies on both sides of the margin of cultivation, for much of the land actually enclosed and occasionally ploughed must be regarded as grass heath. The grass vegetation consists of bents and fescues. Bracken and gorse are frequently present in such amount as to appear dominant. *Galium saxatile* and *Potentilla erecta* are characteristic miscellaneous plants.

Whilst the grass heath soils are generally base-unsaturated, they do not show a high degree of acidity. There is no tendency to the formation of an actual peaty layer, although a matted turf is usual. The grass heath soils have probably been at some time under some sort of cultivation. From the standpoint of soil genesis, they are to be considered as showing incomplete profiles, the surface soil being probably an original B horizon marked by accumulation of sesquioxides.

The grass heaths would probably be the main bone of contention between the forester and the grazier, because they are at the same time the most likely of the waste lands to prove valuable for afforestation and are also the most valuable of the dry rough grazings. In this connexion it may be remarked that

much of the grass heath in North Wales does not appear to be utilized to the full as pasture, even making allowance for the depressed state of agriculture. Large areas are covered with bracken, although it is known that this pest can be exterminated by a limited number of cuttings.

Heath. There is no sharp line of demarcation between the grass heaths and the heaths. There is a type which may be regarded as transitional in which there is a vegetation of fescues and other drought-resisting grasses together with *Ulex Gallii*, *Erica cinerea*, and *tetralix*, and stunted bracken. The soil conditions are more acid and there is a tendency to the formation of a peaty layer. The presence of a peaty layer is generally accompanied by podsolic bleaching, as may be seen when the soil is treated with hydrogen peroxide to remove humic matter. I should be disposed to regard such rudimentary profiles as of secondary origin, developed in what was originally the B horizon. These transitional heaths are less valuable both to the grazier and the forester, for they are at the same time more acid, and more liable to suffer from drought than the grass heaths.

In the typical heaths the vegetation consists mainly of *Erica cinerea* or *Calluna vulgaris* together with *Agrostis spp.*, *Anthoxanthum odoratum*, *Carex panicea*, &c., and a high proportion of such mosses as *Catharinia* and *Rhachomitrium*. The soil is thin and stony or gravelly, passing at a few inches into barren gravel or rock. The formation of a peaty layer is strongly marked and the soil is, as might be expected, strongly acid. The surface soil appears decidedly bleached when organic matter is removed by peroxide treatment. The B horizon, enriched in sesquioxides, generally extends into the parent rock. In some cases the bleached A horizon lies directly on the rock.

In these soils the conditions are such that only plants with small nutrient requirements and great ability to resist drought can survive. The fact that heaths occur most generally in those parts of our area with the highest rainfall does not exempt them from this liability to drought. Indeed, the wet climate has actually brought about these conditions, which are due to the shallowness of the soil and its peaty character, whereby physiological drought sets in even after a week or two of dry weather in the summer months.

We have seen that there is a gradation in the heath series from the desirable grass heaths on the fringe of cultivation to the poorest heather moors. It is of some interest to know whether the general tendency is to degeneration, i. e. the change of grass heath to the less desirable types. Information on this point is not abundant, but observations on the foothills near Bangor suggest that degeneration does occur. There are in the rough grazings of the College Farm, Aber, areas now under a poor vegetation of heather, bilberry, &c., with a pronounced peaty layer and a bleached A horizon which, from the conformation of the ground, must have been under cultivation within comparatively recent times and must, consequently, have passed through the stage of grass which is found over the greater part of these grazings. One may conjecture that the remaining grass heath of this area will in time suffer a similar degeneration unless steps are taken to check the process. The suggestion may

be hazarded that afforestation might prove the necessary check to further degeneration. On the lower levels of the grass heath in question there is a tendency towards the establishment of woodland conditions, for there is an increasing growth of hawthorn, birch, and hazel which will probably, in the absence of interference, result in the formation of a closed woodland.

Sub-alpine Grassland. This type of waste, which has in some respects affinities with the heaths, is scarcely of interest for afforestation. The soil is thin and rocky, and the only possible utilization which can be imagined is the summer pasturage of sheep.

Upland Peat. This type occurs in irregular distribution throughout the mountain area. It develops in situations where the soil is continually water-logged by seepage water from higher ground. The vegetation includes *Eriophorum vaginatum*, deer grass, *Nardus*, clumps of *Molinia* (on the borders of heath), and a fugitive vegetation of *Carices*. The peat is often of considerable depth. Measures of improvement are rendered difficult or impossible by the presence of rock and boulders and by the irregular character of the drainage. Where, however, drainage can be effected by ditches it is possible that such soils might prove afforestable. The fate of the plantings on this type of land near Beddgelert will be of great interest in this connexion.

Lowland Peat. There are in many parts of North Wales areas of lacustrine peat. On account of the general poverty of the waters in mineral matter, these peats are not to be regarded as typical fen. From the point of view of the forester, they call for little consideration, except possibly for willow growing. There are certain stretches of peat over boulder clay which, although occurring in the lowlands, belong more properly to the upland peat type. They are found in many of the mountain valleys and also in stretches in West Carnarvonshire. The peat is of the upland type, of variable depth, and is frequently cut for fuel. In the Lleyn district there is an expanse of poor clay soil resulting from the removal of thin peat from boulder clay. This carries a type of vegetation including *Ulex Gallii*, *Erica cinerea*, and *Molinia coerulea*. It is subject both to excessive wetness and drought. The improvement of the boulder clay peats is extremely difficult on account of the boulders and the irregular drainage conditions. In the Lleyn district the proportion of boulders is not great and improvement is not so difficult. It is possible that some land of this type might be considered for afforestation.

The principal types of waste land in North Wales have now been discussed. It is obvious that many of these types are not of immediate importance for the issue, forestry versus grazing. The soils of the heath series appear to be those over which the issue must be fought. As a layman in forestry, I naturally speak with great diffidence as to the suitability of any particular type of land for afforestation, but my general impression is that value for grazing and value for afforestation run generally parallel, and it is not possible to look for really desirable areas for afforestation in those sections which are of little or no grazing value. In other words, the forester cannot be expected to take the leavings of the sheep grazier.

The decision between forestry and grazing seems to elude a general statement unless some weight is given to future possibilities. If it is to be assumed that rough grazings will be indefinitely maintained at their present value and that the return from forest is to be at its present level, then it would appear that each area is a problem in itself to be settled in the light of local conditions.

There are, nevertheless, certain considerations which, in my view, should be taken into account in any attempt to arrive at a conclusion to this issue. In the first place there is the probability, about which foresters are better able to judge, that the price of timber and therefore the return from forest will rise considerably in the future. In the second place there is the possibility, in many cases the probability, that deterioration will take place in the more desirable hill grazings. There are many grazings in our area which, it seems to me, must decline in value both as pasturage and as potential woodland. There are, on the other hand, localities on the margin of cultivation where trees are establishing themselves on poorly managed grazings. I can only offer suggestions with great reserve, but the conclusion at which I have arrived is that there is a prima facie case for afforestation with coniferous timber on the poorer grass heaths now threatened with deterioration to heath, and with deciduous timber on those areas where woodland is now establishing itself. It does not appear, however, that there are any very extensive blocks of land in North Wales which can be readily spared from grazing and which are at the same time highly desirable for purposes of afforestation.

A Soil Survey of Wales is at present being carried out. As the work is being undertaken primarily on account of the advantages which may be expected to accrue from it to practical agriculture, it is not possible to devote much time and attention to waste lands. From the point of view of possible schemes of afforestation, however, a survey of the waste lands of Wales seems very desirable. As there is a marked correlation between vegetation and soil conditions, such a survey would not be so laborious as a survey of cultivated soils. Indeed, when a little experience had been acquired, aerial photography might be of service, and it would thus be possible to obtain a map of the waste lands of Wales in a comparatively short time.

OAK MILDEW AND ITS CONTROL IN FOREST NURSERIES

BY R. C. WOODWARD, J. S. L. WALDIE, AND H. M. STEVEN

BROAD-LEAVED species and problems have not bulked largely in post-war forestry in Great Britain. Softwoods are the principal need of modern civilization, and afforestation everywhere is being directed to supplying them; for example, over 90 per cent. of the plantations formed by the Forestry Commission have been of conifers. Nevertheless quite a large area of broad-leaved species has been planted by the State since the war—over 4,000 acres to 1927—and the successful establishment of such species as oak presents as difficult, if not more difficult, silvicultural problems than any other species. In the planting of oak in recent years one of the chief difficulties has been the production of good nursery stock, and one of the principal causes of this difficulty has been the widespread and virulent attacks of oak mildew. Further, in the forest both on planted and direct sown stock, success will be more likely if mildew can be controlled under such conditions until the plants begin to get away. The control of oak mildew on young plants is therefore a problem of first importance in successful afforestation with oak.

HISTORY OF THE FUNGUS.

First Occurrence. Oak mildew was recorded[1] for the first time in England in 1908, when it was reported by Mr. Cotton of the Royal Botanic Gardens, Kew, from Exbourne (Devon) in the month of August. The mildew was also recorded as being exceedingly abundant during that season in many parts of the south of England (1). In 1909 Carleton Rea (29) noted its occurrence in Worcestershire on stools of *Quercus pedunculata*. From that date the mildew spread rapidly through the country, and at the present time it can be found wherever oaks are grown in Scotland, England, and Wales.

Distribution. Thumen (35) in 1878 described a mildew on *Quercus racemosa* (*robur*) which had been collected by Mesnier in 1877 in the vicinity of Coimbre, Portugal. To this fungus he gave the name *Oidium quercinum*. After that date there are notes on the occurrence of a mildew on the oak from various parts of Europe, but they are not informative; while Torrend (36), writing in 1909, stated that the fungus had been seen in Portugal around Coimbre for at least sixteen years.

In 1907 Hariot (15) observed a mildew on the oaks in France, and he looked upon it as rather a serious parasite. Towards the end of that year, the oaks in certain parts of Germany, Italy, Spain, and Portugal were seen to be

[1] Mr. W. Dallimore states that he observed this mildew in England prior to 1908.

suffering from attacks due to the parasite. In the following year the mildew was disseminated rapidly throughout Central Europe, appearing to spread from west to east and northwards into Denmark. It was then reported from nearly every European country except Russia, Norway, and the Balkan States. By 1909, however, its diffusion had become more widespread, when it was found simultaneously in various regions of Russia, and in 1910 the oak mildew was observed throughout the whole of European Russia and Rumania. The parasite was found in Norway in 1911, and was then present in all the European countries and Asia Minor.

The growth of the fungus and its spread by conidia (which was the only means of reproduction observed before 1911) progressed so vigorously and swiftly that the young leaves and shoots, particularly on young trees, became entirely covered with the white mycelium and conidia of the mildew. On the leaves it appears at first as small cinnamon-coloured spots, which gradually increase in size and coalesce with one another; this is followed by the withering of the spotted areas and generally accompanied by curling of the edges of the leaves upwards, with the result that they become much distorted. The attention of investigators was further attracted by the remarkable, and for the first time exceptional, predominance of the conidial stage and by the absence of perithecia. These two factors do not permit of establishing with precision the systematic position of the fungus, with the result that some looked upon the mildew as being a recent introduction to Europe, probably from America, where a similar fungus was known to attack several species of oak, and were supported in this view by its spread from west to east. It was believed, therefore, that this was not the fungus which had been previously seen by Thumen in 1878. On the other hand, it has also been thought possible that prior to 1907 the fungus was parasitic on some other species of tree, but about that time changed over to the oak as its host, and as a result assumed a distinct epidemic form.

From 1907 to 1911 only the conidial stage of the fungus was observed in Europe. In the latter year, however, Arnaud and Foëx (2) discovered perithecia on the leaves of *Q. sessiliflora* in France. Since then perithecia have been found in most European countries, but so far they have not been seen in Britain.

Synonomy. The exact determination of the species of mildew on the oak has given rise to considerable differences of opinion, and this is largely due to the controversy about its American or European origin. When Hariot (15) first noted and described the fungus from France, he regarded the conidial stage as similar to *Oidium quercinum* of Thumen. Griffon and Maublanc (14) demonstrated the presence of slight differences in the conidia and decided that it should be made a distinct species—*Oidium alphitoides.* The finding of the perithecial stage by Arnaud and Foëx (2) made it possible to determine the systematic position of the fungus, and they considered it to be identical with the North American form, *Microsphaera quercina* (Schw.) Burr., which has been united by Salmon (31) with *M. alni* as *M. alni* var. *extensa* (Cooke and Peck) Salm. Griffon and Maublanc (14), however, stated that the perithecia differ from all other known forms of *Microsphaera* and gave to it the

name *M. alphitoides*. Behrens (3), Peyronel (25), Buchheim (5), and Wilson (39), who have described perithecia from Germany, Italy, Russia, and Macedonia respectively, agree that it is identical with *M. alni* var. *extensa*, but Blumer (4) prefers, on a basis of the differences in size of the perithecia and the profuse conidial development of the *Microsphaera* on oak, to consider the oak mildew as a separate species, for which the name *M. alphitoides* has precedence. On the other hand, Siemaszko (33) is of opinion that the fungus is of European origin and was not imported from America and should therefore be looked upon as *M. alni* (DC.) Wint. var. *quercina*.

It is possible that the oak mildew at present in Europe ought not to be separated from *M. alni* (DC.) Wint., but, as no perithecia have been seen in Britain, the writers are not prepared to make a definite statement on this question. *M. quercina* the American form is certainly biologically distinct from *M. alni*. Possibly *Oidium quercinum* Thum., which had been seen sporadically on oaks in Europe before 1907, should be regarded as belonging to the European form *M. alni* (DC.) Wint.

Age and Type of Material Attacked. The mildew attacks oaks of all ages but it is most serious on oak nursery stock and oak coppice. On nursery stock the mildew greatly retards growth and also tends to 'kill back' shoots for a considerable distance. Oak coppice is also seriously affected, the shoots dying back. Doé (8 and 9) has advocated the conversion of coppice into high forest as a practical measure in the hope that the virulence of the mildew will decrease in the meantime. On oak coppice and older trees it is the Lammas shoots or those which develop during the summer that suffer most from the disease. When a shoot is heavily infected the mycelium is not only found on the leaves but also spreads to the stem.

Although a number of species of oak are susceptible to the mildew, the most seriously attacked is the pedunculate oak (*Quercus pedunculata*). The pedunculate oak is not only the species most affected by mildew in this country, but is also the one which has been dying off in great numbers in various parts of Europe. The sessile oak (*Q. sessiliflora*), the other important species so far as British forestry is concerned, is less susceptible. This species is much less liable to defoliation by caterpillars and therefore from the severe attacks of mildew that follow such defoliation on the 'summer shoots'. Sessile oak seedlings, however, are almost as susceptible to the mildew in the nursery as the pedunculate seedlings. Turkey oak (*Q. Cerris*) is immune to the disease in this country (23) even when grown in the midst of other oaks heavily infested with the fungus; but in its native habitat in Southern Austria it is severely attacked. Neger (21) gives a list of the majority of susceptible and immune species of oak. In Britain the mildew is also found attacking the beech (*Fagus sylvatica*), very often on stool shoots (6) as well as seedlings. The chestnut (*Castanea vesca*) has been stated by Trotter (37) and others to be susceptible to oak mildew on the Continent, but so far this has not been seen by the writers in this country, even where chestnut was growing in the midst of heavily infested oaks.

Influence of Insect and Frost Damage on its Increase. Munro (19) and Robinson (30) have stated that oaks defoliated by caterpillars such as the Green Tortrix Moth (*T. viridana*) are very liable to attack by the mildew, the oidium infecting the second set of leaves which follow the defoliation. Where the trees have been defoliated for several years in succession, the mildew has caused great damage, with the result that many oaks have died after a few years' continued attack. Until the appearance of the oidium, there is no recorded instance of oaks having been killed solely by the caterpillars.

The same applies when the oak leaves have been damaged by frost. In the Forest of Dean the oaks were severely damaged by the late spring frosts of 1928, with the result that the first crop of leaves were nearly all destroyed, and when the second lot of foliage appeared it was heavily infected by mildew.

LIFE HISTORY OF THE FUNGUS.

Outline of Life History. During spring mildew on oak is not very obvious at first because it is then restricted entirely to the young tissues which 'break' from the buds which were infested with the fungus during the previous season. Some circumstantial evidence of bud infection was obtained on 25th May 1925 in a young plantation of oak near Oxford. At this date 'breaking' buds were seen which were heavily infested with the oidial stage of the mildew. These buds were situated mostly at the base of the previous year's shoots, the upper portion of which had been killed by a severe attack of mildew, and it appeared probable that these lower buds, which were not killed, had been infected by the mildew. Such infections as these may be termed primary, and they serve, under favourable conditions, as sources for the spread of the disease to other tissues and to neighbouring plants. A primary infection is illustrated in Plate II, fig. (*b*). In the mildew of the oak, unlike the mildew of apple, *Podosphaera leucotricha* (41), the number of infected buds which constitute the primary infections is small, but, on the other hand, the less extensive early infection of oak is compensated by the much greater number and virulence of secondary and subsequent infections which are contracted. Given favourable conditions for the spread of the disease, the oak plants are severely attacked during the summer, especially the new sappy growth.

Infestation of Buds by Mycelium. It is not only the foliage on the shoots which become covered with mildew but also the young stem itself when the tissues are not yet toughened. This often leads to the establishment of mildew in the axils of the leaves, which sometimes results in the infection of the axillary buds situated there. The infestation of axillary buds by mildew is not always possible as it depends upon the stage to which the bud-scales have developed. At first these scales are soft and loosely applied and do not afford protection, and it is under such conditions that the mildew enters the bud where the mycelium may become established on the softer tissues of the scales and subsequently between the leaf initials. The position of the mycelium of oak mildew within a young axillary bud is shown in Plate I, fig. (*a*). Haustoria were not found in association with mycelium in oak buds as was the

case with apple (41), but the mycelium found was typical of that of a mildew both in appearance and in its close-lying, characteristic position on the tissues of the host; hence there is little doubt that the mycelium found in oak buds is that of oak mildew. As the buds grow older the scales become tough, cuticularized, and more tightly applied, and then afford complete protection from infestation. The infested buds retain the mycelium in a dormant condition throughout the winter, and this mycelium is not revived into vigorous growth until the following spring, when conidia are produced on the young tissues breaking from them (Plate II, fig. (*b*)). It may be noticed that the mode of perennation in oak buds is very similar to that which occurs in the case of apple, the most notable difference being only the less frequent occurrence of this form of overwintering in oak.

Laubert (17) in 1910 seems to have been the first to point out the possibility of the mildew of oak overwintering in buds, and in the following year (1911), Neger (20) plainly demonstrated that the mildew arose during spring from infested buds on a transplant of *Quercus pubescens* which was under his observation. In 1912 Van Poeteren, in Holland, mentions further suspected cases of over-wintering in oak buds, but until the present investigation the method of bud infestation and the form in which the mildew overwinters in oak buds has not been shown.

Primary Infections. It is of interest to compare the part played by primary (Plate II, fig. (*b*)) and secondary infections (Plate II, fig. (*c*)) in the mildews of the apple and of the oak. In the case of the apple it was found (41) that about 50 per cent. of twigs badly mildewed during a previous season retained mildew in living condition throughout the winter, as seen by the development of the disease on tissues breaking from buds. In oak the percentage is much lower. To find the proportion of oak plants upon which the mildew remains virile in one or more of the buds on a plant, 250 transplants which were severely infected with mildew in 1927 were placed, during the following spring, with roots intact in jars of water in a laboratory free from any external source infection. When the buds opened counts were made of the number of plants with one or more primary infections. These results are shown in Table I:

TABLE I. *Showing the number and percentage of unsprayed plants infected with mildew in* 1927 *which had one or more primary infections in the spring of* 1928

Total no. transplants.	*One primary infection.*	*Two primary infections.*	*Three primary infections.*	*Total plants infected.*	% *Plants infected.*
250	12	6	1	19	7·6

It is seen that the proportion of plants with primary infections arising from buds affected the previous season was 7·6 per cent.

Another lot of severely infected transplants from the same source were potted up with soil and brought to an area free from external infection. An examination of these plants at the time of the bursting of the buds showed that of 190 plants 1·5 per cent. had primary infections, hence it can be seen

that the mildew only occasionally finds access and remains virile in oak buds throughout the winter.

The reason for the smaller percentage of primary infections on oak compared with apple is probably due, firstly, to the less susceptible nature of the oak buds themselves owing to the more rapid hardening of the bud-scales, and, secondly, because oak mildew does not frequently become widespread until later in the summer when the buds have passed the stage of susceptibility to infestation. If, however, new growths or Lammas shoots are produced during this period owing to climatic or other stimulating influences, the infestation of the buds on the new growth takes place, resulting in a greater number of primary infections the following spring.

Germination and Infection Trials with Conidia of Oak Mildew. During June 1925 germination trials were undertaken to determine the viability of fresh conidia of oak mildew. When conidia were placed in water the germination varied between 4 per cent. and 25 per cent., which is greatly in excess of that found in apple mildew (41), but this is not thought to have any bearing on the greater virulence of secondary infections in the case of this mildew, as conidia of apple mildew germinated well on the leaves of the host.[1] It was noted that the germ tubes of germinating conidia of oak mildew caused brown spots on the leaves and also subsequent browning of the leaves as in the case of the apple mildew (41).

The brown spots referred to, which occur at points of penetration by the fungus, are microscopic and, as in the case of the apple, are thought to be caused prior to penetration by some sort of chemical action. Such an assumption is made because of the appearance of the spots, which suggests toxic action, and because of the fact that the area covered by a spot usually comprises a number of host cells, of which only one is apparently invaded at first, as seen by the presence of a haustorium therein.

Endophytic penetration by hyphae has not been noted in oak mildew as in the case of a number of other mildews such as has been noted in *Podosphaera leucotricha* (41), and observed by Klika (16), especially in older leaves during the autumn in *Erysiphe Polygoni*, *E. Cichoracearum*, *Uncinula Aceris*, *Trichocladia Astragli*, and *Sphaerotheca Humuli*.

The Condition of the Host susceptible to Infection. The exact physiological condition of oak leaves which renders them susceptible to infection is not well understood, but there seems little doubt that a change occurs in the cuticle of the leaf on ageing, so that an effective barrier is provided against invasion. In this regard it was noted (41) that, except on very young leaves, infection trials with conidia of *Podosphaera leucotricha* on pear leaves were unsuccessful, whereas the same conidia successfully infected considerably older apple leaves. The rapid thickening of the cuticle of the pear leaf was suggested as an explanation of this. The oak leaf early develops a somewhat stiff texture not very dissimilar to that of the pear leaf, so that both become resistant to attack quite early, probably due to the thickening of the cuticle.

[1] Or on oak leaves (41).

It seems probable also that a high water content of the leaves as found on new growth is a condition which favours susceptibility to infection.

Secondary Infections. In 1928 the first primary infection occurred in transplants at the Forest Nursery at Kennington, on 7th May. Secondary infections were not observed until 14th June, and were then restricted entirely to the under surfaces of the leaves affected. Such infections were not at first very virulent, remaining as spots somewhat round in shape. Later in the summer, when conditions were more suitable for the mildew, the disease spread rapidly to all susceptible parts of the plants. It was noted that in 1928 there was a period of a month or more during which the mildew present in the form of primary and later in the form of restricted secondary infections did not become virulent or widespread. The length of this period undoubtedly changes from year to year and depends on climatic conditions, largely in so far as these affect the growth of the plants and encourage the production of tissues susceptible to infection. When favourable conditions obtain the mildew becomes widespread and severe. In contrast to oak mildew, the mildew on apple trees, although it may be restricted entirely to primary infections, may be very severe on account of the much greater number of such infections.

Overwintering by Other Means. There are other means by which infection of the oak may be started during spring, but in this country, as far as observations have been made, infections other than that derived from infested buds do not occur. Winter spores, called perithecia, which develop on severely infected oak leaves (Plate I, fig. (*b*)) and on beech, have not been observed in Great Britain, although since 1911 (2) they have appeared sporadically in most of the continental countries. The acclimatization of the mildew may be necessary, and it is probable that this is proceeding at the present time. Young seedling plants grown in the greenhouse from acorns were inoculated in 1928 with ascospores from perithecia obtained from Italy,[1] but in no case was successful infection obtained although repetitions are required for confirmation.

Petri (24) in Italy finds that chlamydospores take a prominent part in bringing about infection in spring. These spore-like bodies, first recorded in the mycelium of oak mildew by Ferrari (11) in 1909, may be described as spherical, thick-walled swellings in the mycelium, which remain, according to Petri, on affected leaves which fall and remain on the ground throughout the winter, and are said to be responsible for early infection of the foliage during spring. To discover whether this mode of infection might occur in England, severely infected leaves were repeatedly examined in Oxford for the presence of chlamydospores, but in no case were they found. Nevertheless, it was thought that infection trials should be carried out. In January 1925 young healthy oak leaves were placed in petri dishes to which a little sterile water was added. Small portions of leaves, infected in 1924, were placed on these leaves but no infection ensued. In one case during the spring of 1926, however, infection was successful when clean, leafy twigs in jars of water protected from other external infections were exposed to infection from mildewed dead leaves

[1] Through the kindness of Dr. L. Petri.

of the previous year. Again, in May 1927, three trials were undertaken in the laboratory in which healthy oak leaves were set up in petri dishes containing sterile water; small portions of leaves, infected with mildew in 1926, were placed on these leaves, but in no case did the healthy leaves contract mildew. No successful infection followed many petri dish trials set up in May 1928. In another trial in 1928 seedling plants grown from acorns[1] were submitted to infection which might arise from dead leaves infected in 1927. In this case four glass-covered vessels, containing two plants each, were set up in the open in May, and to three of these vessels an abundance of severely mildewed dead leaves collected in 1927 were added. Water was added according to the requirements of the plants and was also frequently sprinkled on the infected dead leaves which surrounded them. In no case was mildew infection observed during the experiment which terminated in July. During the autumn of 1927 severely affected oak leaves gathered in Oxford were sent to Dr. Petri, who kindly examined the specimens for chlamydospores, but with negative results. As far as these experiments have gone under English conditions the evidence can hardly be said to favour the supposition that fresh infections of mildew are derived from a hibernating form of the mildew on dead leaves infected the previous season.

In summarizing the salient points regarding the life history of oak mildew in England, it is to be noted that the mode of perennation, akin to that of the apple, is a simple one; that the perfect or perithecial stage is absent; that chlamydospores apparently play no part; and that infestation of buds, although occurring only in a small percentage of plants, seems to be the only method of overwintering.

PARASITES OF OAK MILDEW.

During July and later the production of conidia often abates, and the effect produced on the foliage is not so pronounced. In many such cases, examination has shown that parasitism by the dark-coloured fungus *Cicinnobolus* is taking place. This mildew parasite was first recorded on oak mildew by Vuillemin (38) in France in 1910, who identified it as *Cicinnobolus Cesatii* de Bary forma *Euonymi*, F. Tassi. In 1912 Puttemans (26) noted severe parasitism of oak mildew in Brazil by *Cicinnobolus*. The dark-coloured hyphae of this parasite traverse internally the mycelium of its host, and characteristic pycnidia are formed in abundance. These are also dark in colour and sometimes effectively subdue the white appearance of the mildew. There does not seem much doubt that this fungal parasite of mildew is often of considerable importance under English conditions in suppressing the severity of mildew attacks on oak during the latter part of the summer, since the parasite has been observed to be widespread and abundant during the past four years.

A cecidomyid larva resembling a species of *Mycodiplosis* is sometimes

[1] Plants from acorns gathered from the same source were severely mildewed in the Forest Nursery.

abundant and may be seen feeding on mildew on oak leaves. This appears earlier than does *Cicinnobolus* and is often present in great numbers. Neger (21) in 1915 noted on oak mildew what appeared to be the same larval parasite.

RELATIONSHIP TO BEECH MILDEW.

Although it was reported in 1908 by Griffin and Maublanc (14) that oak mildew had another host in beech it was not until 1915 that Neger (21) in Germany first conclusively proved the relationship. In Kent in 1918 the oidial stage of a mildew was observed on beech by Cotton (6), but its connexion with oak mildew was not proved. In 1926, in Oxford, an attempt was made to infect beech leaves with conidia from oak mildew. Young healthy beech leaves were brought into the laboratory and were placed in petri dishes to which a little water had been added. Conidia of oak mildew were scattered on the healthy beech leaves. After six days the healthy beech leaves showed signs of infection, whereas controls, similarly set up but to which no conidia were added, remained free from mildew. Inoculations of oak leaves with mildew from beech were similarly successful. Similar trials were successfully repeated early in the summer of 1927. The results of these trials are in agreement with those of Neger, who found that oak mildew could be transferred to beech leaves and vice versa, and that, therefore, the two diseases appeared to be identical. The mildew on beech is seldom, if ever, found on older growth but is confined to the young leaves, especially to those on Lammas shoots or coppice growth, and on seedlings and transplants in the nursery. As yet it is not of much economic importance although some severe cases have been noted in nurseries.

EXPERIMENTAL DATA ON CONTROL.

Previous Work on Control. Oak mildew was recognized as a serious disease in forest nurseries from the beginning of its spread in Europe, and it was realized that this was the first point at which the mildew should be attacked. In 1909 Raux (28) carried out spraying experiments with solutions of common salt (sodium chloride), and found that good results were given on old leaves with a 3·3 per cent. solution with soft soap as a 'spreader'; on the more tender young leaves a 2 per cent. solution was used, when two applications were necessary to clear the mildew. In the same year Cuif (7) carried out experiments with flowers of sulphur, dusted on the plants. Three treatments—at the end of May, at the beginning of July, and again in August—kept down the mildew, and thus increased the growth of the oak. In 1915 Neger (21) discussed the effect of different treatments tried up to then, such as hot water, sulphur, lime-sulphur, polysulphide, &c. He got good results with a 5 per cent. lime-sulphur mixture. Wimmer (40) in 1924 found that a 1 per cent. colloidal sulphur spray was efficient in the control of mildew, while strengths up to 4 per cent. did not injure the foliage. Two years later Oppenheimer (22) confirmed this, using Cosan. He found that sodium chloride solution burned the foliage.

Experiments, 1926. In 1926 there were a considerable number of both sessile and pedunculate oak seedlings in Bagley Nursery, Oxford, and they

were all heavily mildewed. A small preliminary experiment was carried out to study the control of the fungus. Flowers of sulphur were dusted on to the plants, and a 1 per cent. solution of common salt was tried also. The sulphur produced no appreciable effect, while the salt scorched the leaves, although the spraying was done in dull weather.

Experiments, 1927. In 1927 more extensive and intensive experiments were carried out at Kennington Nursery, Oxford, and at Rhinefield Nursery, in the New Forest. At Oxford rising one-year seedlings (i.e. plants from acorns sown in the spring, 1927) and rising one-year one-year transplants were studied, while in the New Forest rising two-year seedlings were used.

The following treatments constituted the experiment, each treatment being repeated several times, and on both sessile and pedunculate oak:

1. Control, no treatment.
2. Ammonium polysulphide, ½-gallon in 100 gallons of water (0·5 per cent.).
3. Lime-sulphur, 1 gallon in 100 gallons of water (1 per cent.).
4. Ialine colloidal sulphur, 4 lbs. per 100 gallons of water (0·4 per cent.), 0·3 per cent. in the New Forest.
5. Cosan colloidal sulphur, as Ialine.

Three pounds of casein per 100 gallons were added to each spraying mixture as a 'spreader'. The ammonium polysulphide and lime-sulphur sprays were made in the usual way, for example, according to Eyre, Salmon, and Wormald (10) and Salmon (32) respectively. Colloidal sulphur sprays are easily prepared. The required quantity of colloidal sulphur is taken and added to a similar amount of water; this is then stirred into a thin cream which is added to the required bulk of water containing the casein, and the whole is well stirred up, when it is ready for use. The spraying was only carried out during dull days, or during the late afternoon, so as to minimize the danger of scorching.

The first spraying was made when the mildew was first noticed, which was on the 23rd May, at Rhinefield, and on the 16th June at Kennington. The spraying was repeated every two to four weeks, depending on the growth of the oak and the progress of the mildew, five sprayings being given in all, the last being on the 30th August at Rhinefield and on the 3rd September at Kennington. One gallon of mixture sprayed 175 sq. ft. per application.

In both nurseries the plants in the untreated plots were covered with mildew, and the leaves were shrivelled. The most efficient treatments were the colloidal sulphur sprays, and after the third application the plants were practically free from mildew (see Plate II, fig. (*a*)), while there were no signs of scorching on the young leaves and shoots. Compared with the controls, one of the most striking features in the colloidal sulphur-treated plots was the good growth which the plants, freed from mildew, put on in August. The foliage was a deeper green, the leaves longer, and not shrivelled. The lime-sulphur-treated plants were comparatively free from mildew, but the young growth in all the plants showed signs of scorching by the spray. Ammonium polysulphide was less efficient in reducing the mildew, particularly in the New Forest.

It has been stated that light and warmth favour the development of the mildew, and it is commonly observed that young oak growing under bracken or other plants is relatively free from mildew. The effect of sheltering rising one-year oak seedlings with lath shelter was tried, but with negative results, the plants being as heavily mildewed as those in the open.

This season's work showed that colloidal sulphur sprays, both Ialine and Cosan, repeated at intervals of about three weeks, were efficient in controlling the mildew without adversely affecting the trees, and that absence of the mildew was reflected in more vigorous growth of the oak.

Experiments, 1928. In 1928 more detailed experiments were carried out in the same two nurseries, concentrating on the colloidal sulphur sprays, and studying different strengths and numbers of applications.

EXPERIMENT No. 1, SESSILE OAK, ONE-YEAR, OXFORD.

Plant material: Rising one-year seedlings from reputed sessile oak acorns from Hartz Mountains, Germany, sown on 6th April 1928. The seedlings were not pure sessile as the following classification of leaf characters shows:
Auricles and no stellate hairs (pedunculate type): 19 per cent. of seedlings.
Auricles with hairs (hybrid type): 34 per cent.
No auricles with stellate hairs (sessile type): 47 per cent.

Unit plot: 5 feet by 3 feet. For purposes of analyses the middle strip, 1 foot by 3 feet, was taken.

Lay-out: Four replications in randomized blocks.

Treatments: Three sulphur sprays were used:

(*a*) Cosan colloidal sulphur.
(*b*) Ialine colloidal sulphur.
(*c*) Flowers of sulphur made up with water and calcium caseinate or soft soap into a paste.

Two strengths were used; 2 pounds and 4 pounds per 100 gallons of water. The water was soft, 5° of hardness, and soft soap at the rate of 4 pounds per 100 gallons was used as a 'spreader'. At the first spraying it gave unsatisfactory results as regards mixing with the flowers of sulphur, and calcium caseinate was substituted for the soft soap in the subsequent sprayings with that substance. One gallon of spray was used per 65 square feet, there being about 25 plants per square foot.

One, two, and three applications were tried, and at the following dates:

(*a*) One application on the 5th July 1928.
(*b*) Two applications on the 5th July and 8th August 1928.
(*c*) Three applications on the 5th July, 8th August, and 18th September 1928.

Analysis: An analysis was made of all the plants in 3 square feet in each plot of each treatment noted in Table II, except for dry-weights, when 10 plants per plot were taken, selecting every fifth plant. The results were subjected to statistical analyses by Fisher's method for Randomized Blocks, where all treatments were involved, and by Student's method, where two only were compared (see Steven (34) for description of these methods).

Table II shows the influence of the different treatments under the conditions of the experiment. The most marked effects have been, first of all, that the treatments have kept about one-half the plants entirely free from mildew, and,

TABLE II. *Sessile Oak, One-Year*

Treatment.	*Without mildew.* %	*Mildew infection.* *With dead mildew.* %	*With live mildew.* %	*Mean ht. of plants. Inches.*	*Mean no. of leaves per plant.*	*Mean Size of leaf. Inches.*	*Dry-weight per plant. Grammes.*
1. Control	4	93	3	4·6	9	2·1	0·86
2. Cosan, 4 lb. 1 spraying	47	48	5	5·4			
3. Cosan, 2 lb. 2 sprayings	46	51	3	5·1			
4. Cosan, 2 lb. 3 sprayings	53	45	2	5·1			
5. Cosan, 4 lb. 2 sprayings	60	39	1	4·8			
6. Cosan, 4 lb. 3 sprayings	52	48	0	4·8			
7. Ialine, 2 lb. 2 sprayings	54	42	4	4·6			
8. Ialine, 2 lb. 3 sprayings	54	45	1	4·9			
9. Ialine, 4 lb. 2 sprayings	55	44	1	5·5			
10. Ialine, 4 lb. 3 sprayings	53	46	1	4·7			
11. Sulphur, 2 lb. 2 sprayings	52	45	3	5·3	11	2·3	1·46
12. Sulphur, 2 lb. 3 sprayings	53	46	1	5·1			
13. Sulphur, 4 lb. 2 sprayings	55	43	2	5·2			
14. Sulphur, 4 lb. 3 sprayings	47	53	0	5·0			
Standard error	3·7	—	—	0·24	0·4	0·08	0·10
Difference required to give a 20 to 1 probability of significance	11·9	—	—	0·76	1·3	0·25	0·32

secondly, this freedom from mildew has resulted in a 70 per cent. increase in the dry-weight of the plants, no doubt as the result of greater photosynthetic activity. The increase in size of seedling is small and not significant on the whole. This was probably due to the weather conditions of the summer of 1928; during June and July the weather was hot and dry and this probably inhibited the growth on the light, sandy loam of the nursery. The increase in the number of leaves per plant is small, but significant, while the difference in mean size of leaf is not significant. The small amount of live mildew on the

leaves of the plants by autumn is interesting. The death of the mildew was probably due in part to the resistance of the oak leaf to the spread, and thus to the life, of the fungus, it being an obligate parasite, and partly to the ravages of *Cicinnobolus*, the fungus parasitic on it.

The three substances used for spraying have given similar results, the mean percentage of the plants free from infection for Ialine, Cosan, and flowers of sulphur being 54 per cent., 53 per cent., and 52 per cent. respectively. Further, taking the one spraying, and the means of all the plots receiving two and three sprayings, and similarly the data for the 2 and 4 pound strengths, no significant differences appear.

Thus, for the conditions of this experiment, even one and two sprayings of any of the three substances at the rate of 2 lb. per 100 gallons of water was efficient in controlling the disease. The success of one or two sprayings was probably due to rather special conditions of the weather and the nursery. The dry weather decreased the amount of new and thus susceptible growth during the summer, and there was little infected material in the nursery owing to the general application of spraying, while there were no oak woods in the immediate vicinity.

Experiment No. 2. Pedunculate Oak, One-Year, Oxford.

A similar experiment was carried out on pedunculate oak seedlings from acorns sown on the 28th November 1927. These acorns germinated earlier than the sessile in Experiment No. 1, and the mildew infection, although appearing earlier, namely, the 12th June, was not so virulent, probably due to the leaves being more leathery when the maximum infection took place. The analyses at the end of the season gave similar results to those of Experiment No. 1, the spraying with colloidal sulphur and flowers of sulphur increasing markedly and significantly the percentage of the plants free from mildew, and the dry-weight of the plants. One spraying, however, gave significantly less protection than the mean of two and three sprayings.

Experiment No. 3. Sessile Oak, One-Year, New Forest.

Plant material: Rising one-year seedlings of sessile oak.

Unit plot: 1 seed-bed.

Lay-out: No replications, except 3 controls.

Treatments: Similar to Experiment No. 1, but no flowers of sulphur.

The times of application of the sprays were:

(*a*) One application, 3rd July 1928.
(*b*) Two applications, 3rd and 26th July 1928.
(*c*) Three applications, 3rd and 26th July, and 15th August 1928.

This experiment fully confirmed the two just described (see Table III) in that the spraying materially reduced infection by mildew, and increased the dry-weight of the plants. It gave further data, however, which were probably due to the conditions in the nursery where the experiment was conducted. Rhinefield Nursery has a heavier soil than Kennington Nursery, Oxford, hence the growth is less likely to be checked during dry, hot weather. Further, it is

surrounded by oak woods, hence infection by conidia is more likely to be continuous during the summer. Thus spraying increased the size of the plants appreciably, and three sprayings were more effective both in decreasing the mildew and increasing the size and weight of the plants than two sprayings, which in turn were better than one. On the whole Ialine gave better results than Cosan, and 4 lb. than 2 lb., but it is doubtful if the differences would be significant, if it had been possible to calculate standard errors.

TABLE III. *Sessile Oak, One-Year, New Forest*

Treatments.	*Percentage of plants free from mildew.*	*Mean height of plant in inches.*	*Dry-weight per plant in grammes.*
1. Control	30	3·5	0·80
2. Cosan, 2 lb., 1 spraying	40	4·3	0·92
3. „ 2 lb., 2 sprayings	53	5·0	1·05
4. „ 2 lb., 3 sprayings	53	5·2	1·46
5. „ 4 lb., 1 spraying	40	4·0	0·83
6. „ 4 lb., 2 sprayings	62	4·3	1·07
7. „ 4 lb., 3 sprayings	73	5·9	1·20
8. Ialine, 2 lb., 1 spraying	45	4·0	0·94
9. „ 2 lb., 2 sprayings	55	4·5	1·02
10. „ 2 lb., 3 sprayings	81	4·9	1·21
11. „ 4 lb., 1 spraying	46	4·0	0·89
12. „ 4 lb., 2 sprayings	69	5·0	1·31
13. „ 4 lb., 3 sprayings	88	6·7	1·88

EXPERIMENT No. 3. SESSILE OAK, ONE-YEAR ONE-YEAR, OXFORD.

At Kennington Nursery, Oxford, sections of rising one-year one-year sessile oak, spaced 10 inches by 2 inches were sprayed with Ialine at the rate of 4½ lb. per 100 gallons, soft soap to a like amount being added as a 'spreader'. A control, unsprayed, was left. The plants had not been sprayed during the first year of their growth, and the first spraying was made on the 24th May 1928, against primary infections. The second was carried out on the 20th June when the secondary attack was developing on the first crop of leaves. On 13th July the mildew was spreading on to the new leaves of the second growth, and a third spraying was carried out. The final one was made on the 21st August. At each spraying 1 gallon of mixture sprayed 245 sq. ft., there being approximately seven plants per sq. ft. At the end of the season an analysis showed that in the control only 3 per cent. of the plants were free from mildew, compared with 56 per cent. in the sprayed sections; the respective mean heights of the plants were 3·5 and 3·8 inches.

EXPERIMENT No. 5.

A large scale spraying experiment, using Ialine 4 lb. per 100 gallons with the same amount of soft soap, was carried out in seventeen of the Forestry Commission nurseries where oak stock is raised. The number of sprayings varied from three to five, and a wide range of plant material was used, pedunculate

and sessile, seedlings and transplants. In every instance the divisional officers' reports showed that the spraying had decreased the mildew infection, re-infection not taking place until three or more weeks after treatment. In order to keep the plants clean, spraying had to be continued until September. The absence of the mildew in some instances produced a notable increase in the size of the plants, up to 100 per cent. compared with the controls being recorded, while in other instances there was no effect on size. This difference in effect on size was probably connected with local weather and soil conditions, as already noted.

Effect of Spraying on Subsequent Infection and Growth. The seedlings sprayed and unsprayed in 1927 at Kennington were lined out on separate but contiguous plots in 1928, there being in all twenty-nine pairs for further comparison. The lots sprayed in 1927 were sprayed again in 1928, Ialine at the rate of 4 lb. per 100 gallons being used, with three applications. The lots unsprayed in 1927 were left unsprayed in the following year.

The first comparison made was the amount of primary bud infection in sprayed and unsprayed lots in the spring of 1928. The datum was 1·1 per cent. of the sprayed plants showed primary infection compared with 5·2 per cent. for the unsprayed, a difference of $4{\cdot}1 \pm 1{\cdot}9$ in favour of the sprayed plants. This again emphasizes the small success which this fungus has in penetrating into, and overwintering in the bud, and spraying still further reduces this success.

One of the difficulties of raising good nursery stock of oak has been due to the dying of terminal buds and shoots, thus causing bushy plants, and it has been uncertain how far this is due to mildew. At the end of the second season the percentage of plants with a good leader was determined in the twenty-nine lots raised from acorns of different origins, half of each lot being sprayed during the two years and half unsprayed. There was considerable variation in the percentages for the different lots, suggesting that this die-back was due in part to factors of genetic origin, but the mean for the sprayed plants was 40 per cent. compared with 31 per cent. for the unsprayed, the difference $9 \pm 2{\cdot}0$ being appreciable and significant. Spraying had, therefore, definitely increased the proportion of plants with good leaders.

Discussion of Results. An intensive study has been made of methods of controlling mildew on young oak plants. In rising one-year seedlings, infection by conidia takes place during June, when the leaves, shoots, and buds are in a susceptible condition, and this is undoubtedly the critical period when protection should be afforded, otherwise the mycelium penetrates into the buds and the fungus continues on the plant. The tender condition of the foliage during this stage makes it necessary to avoid sprays which scorch, such as 1 per cent. sodium chloride and lime-sulphur. Experiments with colloidal sulphur carried out during two seasons and in almost a score of nurseries showed that this substance causes no damage whatsoever to the plants.

Sprays with colloidal sulphur or flowers of sulphur, and containing soft soap or calcium caseinate as 'spreader', deposit a thin film on the leaves, shoots, and

buds, and it has been shown conclusively that this not only destroys the mildew present at the time of application, but prevents the development of mycelium and conidia in new infections for a period of at least three weeks. During this period the leaves pass into a less susceptible condition owing to the hardening of the cuticle, &c. When new growth develops, further susceptible material is produced, and spraying is again necessary. The number of sprayings required in a season depends on the rate of growth of the oak, and the amount of infected material in and surrounding the nursery. Under conditions unfavourable to the mildew—that is, with little second growth on the oak, and few centres of infection—it has been shown that one spraying in June or early July gives effective protection, but generally three to five sprayings are necessary during the season. The three substances, Ialine, Cosan, and flowers of sulphur, are equally effective, and the first or last is recommended, being easily obtainable. The experiments indicated that 2 lb. per 100 gallons is a minimum amount, as this was not always as effective as 4 lb. As the difference between 2 and 4 lb. was small, it appears improbable that any increase in the latter amount would give improved results. Two to four pounds is recommended, therefore, depending on the seriousness of the attack expected. On the whole, calcium caseinate proved a more efficient 'spreader' than soft soap.

The treatments described greatly reduced the amount of mildew, more than half the plants being entirely free from infection, while the sprayed plants infected were only slightly attacked. The leaves of the oak were thus enabled to fulfil their functions, and this was reflected in a notable increase in the dry-weight of the plants. Under certain conditions, also, better height growth was made. Spraying also decreased the amount of bud infection and increased the proportion of transplants with good leaders.

The experiments described were official ones carried out for the Forestry Commission, and the results are published by the kind permission of the Forestry Commissioners. We also wish to make acknowledgements to Mr. L. S. Osmaston, Deputy Surveyor, the New Forest, who co-operated in the experiments there, and to different Divisional Officers of the Forestry Commission, on whose reports Experiment No. 4, 1928, is based.

SUMMARY.

1. Oak mildew is a serious disease on young oak plants, making afforestation by that species more difficult.

2. The earliest record of it in Great Britain was from Devon in 1908; it is now generally distributed.

3. It appeared as an epidemic in France in 1907, and spread rapidly from west to east through Europe. Until 1911 only the conidial stage was seen, and so far in Britain no perithecia have been observed.

4. Some consider the fungus to be the American form of *Microsphaera*, viz. *M. alni* var. *extensa* (Cooke and Peck) Salm; others the European form *M. alni* (DC.) Wint.; and some a distinct species, *M. alphitoides* Griff. and Maublanc.

5. The mildew attacks oak of all ages, but is most severe on seedlings and coppice. Most commonly found on *Quercus pedunculata* and *Q. sessiliflora*, it also occurs on beech in this country, and has been recorded on Sweet Chestnut on the Continent.

6. Where the oaks have been defoliated by caterpillars or damaged by frost, the second set of leaves is very frequently attacked by mildew.

7. Axillary buds of oak are invaded by the mycelium of the mildew, after infection of the young shoots, and the position of the mycelium between the young leaf initials is described and figured. Reference was first made to the overwintering of mildew in oak buds by Laubert in 1910, and subsequently by Neger and van Poeteren, but until the present investigation the method of bud infestation, and the form in which the mildew overwinters has not been shown.

8. On severely mildewed plants only 1·5 to 7·6 per cent. show successful overwintering in the buds; this compared with 50 per cent. in the case of apple mildew. This difference is probably related to the more rapid hardening of the bud-scales of oak, and to its mildew not becoming widespread until later in the summer, when the buds are no longer susceptible to infection.

9. The germination of the conidia in water varied from 4 to 25 per cent. On oak leaves the germ tubes cause minute brown spots on the underlying tissues, due, it is suggested, to chemical action.

10. The endophytic penetration of oak mildew was not observed, but frequently the mildew caused the whole leaf to turn brown, with subsequent defoliation of the plants.

11. In 1928 at Oxford the first primary infections were observed on the 7th May. Secondary infections were observed on the 14th June, but they did not become virulent until later in the summer, when new growth made conditions more suitable for the fungus, thus demonstrating the influence of climatic conditions on the spread of the disease.

12. No success was obtained in England with ascospore inoculations, using perithecia from Italy.

13. Petri in Italy finds that chlamydospores take a prominent part in causing infection during spring, but experiments did not confirm the presence of chlamydospores in England.

14. Two parasites of oak mildew are common, namely, *Cicinnobolus Cesatii* de Bary, and a cecidomyid larva resembling a species of *Mycodiplosis*. The former is considered to be of some importance in suppressing severe mildew attacks during the late summer.

15. Successful inoculations of oak mildew from oak to beech and vice versa are described, confirming those of Neger.

16. Several experiments are described dealing with the control of mildew on young oak plants, and the effect of successful control.

17. Sprays using 1 per cent. sodium chloride and lime-sulphur burned the young foliage, flowers of sulphur as a dust was not successful, and ammonium

polysulphide only partially efficient. Sheltering of the young plants did not reduce the mildew.

18. Sprays using colloidal sulphur—Ialine, and Cosan—and flowers of sulphur made up as a paste, at the rate of 2 to 4 lb. per 100 gallons, successfully controlled the mildew. Calcium caseinate was a more efficient 'spreader' than soft soap. The number of applications necessary per season varies with the growth of the oak and the amount of infection. Under favourable conditions one may be sufficient, but usually three to five are necessary, the first one being made when the mildew first appears.

19. These treatments secure that more than half of the plants are kept entirely free from mildew, height growth may be increased, and there is a great increase in the dry-weight of the plants. Bud infection is decreased, and the proportion of plants with good leaders is increased.

REFERENCES

(1) Anon.: 'Notes on Insect, Fungus, and other Pests.' *Journ. of Bd. of Agric.*, xv, p. 440, 1908.

(2) Arnaud et Foëx: 'Sur la Forme de l'Oïdium du Chêne en France.' *Comptes rendus Acad. Sc. Paris*, t. 154, p. 124, 1912.

(3) Behrens, J.: 'Die Perithecien des Eichenmehltaus in Deutschland.' *Zeit. für Pflanzenkr.* xxxi, p. 108, 1921.

(4) Blumer, S.: 'Die Perithecien des Eichenmehltaus (*Microsphaera alphitoides* Griff. et Maubl.).' *Mitt. Naturforsch. Gesellsch. Bern*, 1924, p. xliv, 1925.

(5) Buchheim, A.: 'Zur Kenntnis des Eichenmehltaus.' *Zeit. für Pflanzenkr.* xxxiv, p. 1, 1924.

(6) Cotton, A. D.: 'The Occurrence of Oak Mildew on Beech in Britain.' *Trans. Brit. Mycol. Soc.*, vi, pt. 3, p. 198, 1919.

(7) Cuif, E.: 'L'Oïdium du Chêne.' *Rev. des Eaux et Forêts*, t. 50, p. 270, 1911.

(8) Doé, F.: 'La Conversion en Futaie et l'Oïdium. *Rev. des Eaux et Forêts*, t. 57, p. 53, 1919.

(9) —— 'L'Oïdium et les Forêts feuillues du Nord-est de la France.' *Rev. des Eaux et Forêts*, t. 61, p. 429, 1923.

(10) Eyre, Salmon, and Wormald.: 'Ammonium polysulphide wash.' *Journ. Min. Agric.*, vol. xxvi, p. 821, 1919.

(11) Ferrari: *Annales Mycologici*, vii, 1909.

(12) Griffin et Maublanc: 'Le Blanc du Chêne et l'Oïdium quercinum.' *Bull. Soc. Mycol. France*, t. xxvi, p. 132, 1910.

(13) —— 'Les Microsphaera des Chênes et les Périthèces du Blanc du Chêne.' *Comptes rendus Acad. Sc. Paris*, t. 154, p. 935, 1912.

(14) —— 'Les Microsphaera des Chênes.' *Bull. de la Soc. Mycol. de France*, t. xxviii, p. 88, 1912. (Planches III, IV, and V.)

(15) Hariot, P.: 'Note sur un Oïdium du Chêne.' *Bull. Soc. Mycol. de France*, t. xxiii, p. 157, 1907.

(16) Klika, J.: 'Einige Bemerkungen über die Biologie des Mehltaues.' *Ann. Mycol.*, xx, p. 74, 1922.

(17) Laubert: *Praktische Blätter für Pflanzenbau und Pflanzenschutz*, 1910.

(18) Marchal et Foëx: 'Rapport phytopathologique pour l'année 1925.' *Ann. des Épiphyties*, xi. 6, p. 412, 1925.

(19) Munro, J. W.: 'The Relation of Forest Pathology to Silviculture.' *Rep. Proc. Imp. Bot. Conf.*, p. 187, 1924.

(20) Neger, F. W.: 'Die Überwinterung und Bekämpfung des Eichenmehltaus.' *Thar. Forst. Jahrb.*, 62, p. 4. 1911.

(21) —— 'Der Eichenmehltau.' *Naturwiss. Zeit. für Land- und Forstw.*, 13, p. 1, 1915.

(22) Oppenheimer, H. R.: 'Die Therapie der Baumschulkrankheiten.' *Angew. Bot.*, viii, p. 137, 1926.
(23) Osmaston, L. S.: 'Mortality among Oak.' *Quart. Journ. For.*, xxi, No. 1, p. 28, 1927.
(24) Petri, L.: 'Osservazioni ed esperienze sull' oidio della querce: I. Formazione di organi referibili a clamidospore; II. Azione dei raggi ultravioletti sopra i conidi.' *Annali del R. Instituto superiore forestale nazionale*, ix, 1924.
(25) Peyronel, B.: 'Observations on the perfect Form of the Oak Oidium in Italy.' *Le Staz. sperim. agrar. ital.*, 54, p. 5, 1921 (ref. in *Int. Rev. Sc. and Pract. Agric.*, 12, p. 643, 1921).
(26) Puttemans, A.: *Bull. de la Soc. de Path. Vég. de France*, vii, pt. 1, p. 37, 1920.
(27) Van Poeteren, N.: 'De Overwintering en Bestrijding van eenige meeldauzwammen.' *Tidjschr. over Plantenziekten*, p. 1, 1912.
(28) Raux, M.: 'Un remède contre l'Oïdium du Chêne.' *Rev. des Eaux et Forêts*, t. 48, p. 686, 1909.
(29) Rea, C.: 'New and Rare British Fungi.' *Trans. Brit. Myc. Soc.*, iii, p. 230, 1910.
(30) Robinson, R. L.: 'Mortality among Oak.' *Quart. Journ. of For.*, xxi, No. 1, p. 25, 1927.
(31) Salmon, E. S.: 'A Monograph of the Erysiphaceae.' *Mem. Tor. Bot. Club*, ix, 1900.
(32) —— 'Lime-sulphur as a Fungicide.' *Journ. Min. Agric.*, vol. xxviii, p. 995, 1922.
(33) Siemaszko, W.: *Rev. Appl. Mycol.*, v, p. 524, 1926.
(34) Steven, H. M.: 'Nursery Investigations.' *Forestry Commission Bull.*, No. 11, 1928.
(35) Thumen: 'Contrib. ad Floram.' *Mycol. Lusit.*, p. 6, 1878.
(36) Torrend, G.: 'L'Oïdium du Chêne en Portugal et l'Île de Madère.' *Broteria*, Ser. Bot. viii, p. 103, 1909.
(37) Trotter, A.: '*Oidium quercus* on Chestnut Trees in Italy.' *L'Alpe*, ser. ii, Year III, No. 2, p. 49.
(38) Vuillemin, P.: 'Le Blanc du Chêne entravé par un ennemi naturel (Cicinnobolus).' *Comptes rendus Acad. Sc. Paris*, p. 647, 1910.
(39) Wilson, M.: 'The Oak Mildew.' *Trans. Roy. Scot. Arb. Soc.*, xxxvi, p. 92, 1924.
(40) Wimmer: 'Fortschritte auf dem Gebiete der Bekämpfung von Pflanzenschädlingen.' *Forstwiss. Centralbl.*, xlvi, p. 493, 1924.
(41) Woodward, R. C.: 'Studies on *Podosphaera leucotricha* (Ell. & Ev.) Salm.' *Trans. Brit. Myc. Soc.*, xii, pt. ii, 1927, pp. 174, 179, 188, 193, 196, 199.

EXPLANATION OF PLATES I AND II

PLATE I.

Fig. (*a*). Transverse section through a young axillary bud of oak, showing semi-diagrammatically the distribution of the septate mildew mycelium between the leaf initials on the 15th June 1925. The bud scales are not shown as they were removed to facilitate fixing prior to microscopical preparation. ×45.

Fig. (*b*). Perithecia on oak from Italy. ×15.

PLATE II.

Fig. (*a*). Oak one-year seedlings, unsprayed, and sprayed with colloidal sulphur, 1927.

(*b*). Branch of oak showing primary infection from a bud.

(*c*). Branch of oak showing secondary infection from conidia.

Fig. (*a*). Transverse section through a young axillary bud of oak, showing semi-diagrammatically the distribution of the septate mildew mycelium between the leaf initials on the 15th June 1925. The bud scales are not shown as they were removed to facilitate fixing prior to microscopical preparation. ×45.

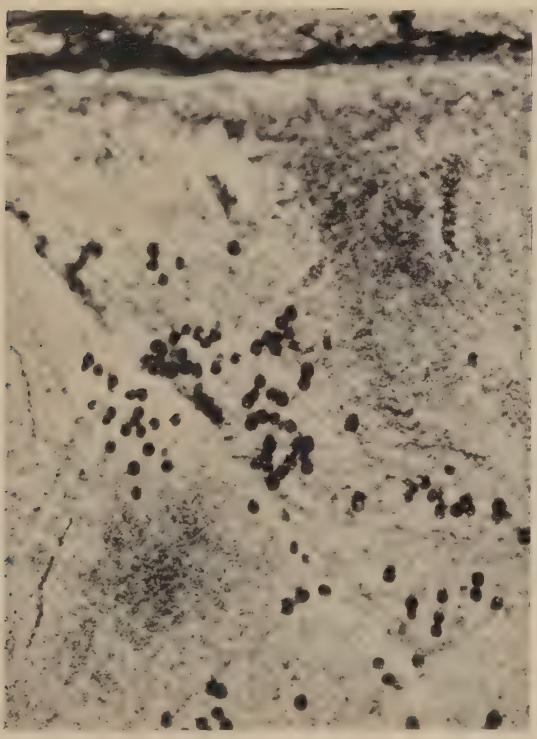

Fig. (*b*). Perithecia on oak from Italy. ×15.

PLATE I

Unsprayed *Col. sulphur*

Fig. (*a*). Oak one-year seedlings, unsprayed, and sprayed with colloidal sulphur, 1927.

Fig. (*b*). Branch of oak showing primary infection from a bud.

Fig. (*c*). Branch of oak showing secondary infection from conidia.

PLATE II

WOODWORKING MACHINERY, WITH SPECIAL REFERENCE TO THE BUILDING TRADE

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BY the introduction of modern woodworking machinery the day of the handcraftsman has practically come to an end. Even in the shops where the working is by hand the timber is bought already machine sawn, planed, and moulded; which really means that the handcraftsman and his work began to take second place when the pit sawyer gave way to the more rapid machine.

In this article an attempt will be made to introduce the reader to some of the principal woodworking machines, commencing with a reference to four important developments.

The first of these is the *log band saw*, used for the rapid breaking down of logs. In Great Britain these machines carry band saws from 6 inches to 11 inches in width, but in America they are used much wider and in some mills cut with both edges; such saws being described as double-cut saws. Careful attention must be given to band saws to get good results, and they are best left to the care of a skilful saw doctor. The saws are rolled to give tension, and may be either spring-set or swage-set, i.e. in one case the tooth is bent over in one direction and in the other the cutting end of the tooth is spread out, on both sides, to the desired width. A side-dresser is used to ensure an equal spread of the teeth and so a smooth surface to the timber when converted.

As a side-issue it may be mentioned that the making of the bands or hoops for ladies' crinolines was responsible for the development of the small band saw and consequently the log band saw. The French were pioneers in the making of these steel hoops and this experience gave them an advantage in the manufacture of the band saw.

The second was the discovery of *high speed steel*, and this will be referred to again.

The third important development was the coming of the *ball race* which revolutionized the machine, and we can now get what every good craftsman wants, namely, plenty of speed without loss of power. If the bearings are carefully looked after and washed out now and again with paraffin, not overdone with grease but given a good quality grease, free from acids, we then have something really serviceable and of which we can be proud.

The fourth or latest addition to the woodworking machine is the *direct coupled motor*, although this is not yet working as it ultimately will when we can have all our electric current transformed from alternating to direct. This addition will provide more room in our Machine Shops; further, the current

can be easily switched on and off and no power is wasted when the machine is standing, or 'grinding wind', as the old masters had it.

In a Building Trade shop after the timber has been cross-cut to length, usually by a pendulum or other cross-cut saw, the pieces for panel door stiles, rails, sash bars, &c., are passed on to the *rip saw bench*. Here a circular saw from 24 inches diameter up to 32 inches may be used, but it is advisable to use a saw just large enough for the job in hand, inserting a larger saw for deeper cutting. These saws should develop a peripheral speed of from 9,000 to 10,000 r.p.m., a good speed making hand-feeding much faster and easier for the operator. A fairly thin gauge may be used, not more than 12 B.W.G., so as to save material.

The saw, after being mounted on the spindle and held well back on the pin till tightened up, should then be packed. Two strips of softwood, say of yellow pine, evenly wrapped with thin hemp make a good packing. The hemp may be pressed up from each end so as to make the packing a little thicker in the middle; this slightly warms up the centre of the saw and makes the rim stand up stiffer.

For softwood a fairly wide spaced tooth is advocated, with plenty of hook on the front, filed to a slight bevel on the top. Where both medium-hard and soft woods are to be cut, the teeth should be closer together and not so much hooked on the front. The canting fence now supplied with these saw benches allows all kinds of bevels to be cut, and the rise and fall table and rise and fall spindle both allow rebating or grooving to be done. Some benches are fitted to take 'drunken' saws and large grooves can then be cut quite easily.

In good-class joinery, after the rip saw comes the surfacing, or the trueing up, of the pieces. *Surfacing machines* are now all fitted with the circular cutter block—a Home Office order—which makes them much safer to operate. The speed of this machine is up to 5,000 r.p.m. The cutters are of thin high-speed steel, carefully ground to prevent burning the edges and so spoiling the steel. The cutters are expensive, but do a great amount of work and, when the above precautions are taken, carry the cutting edges for a long time. Some makers advocate wet grinding, but if care is taken not to hurry the grinder cut, the dry grinder does the job quite well and much cleaner. For general purposes the bevel should be from 30° to 45° and the cutters honed to a fine edge, all traces of wire edges being removed with a good-class oilstone slip. Further, care should be taken to see that the cutters are quite straight and well balanced before mounting on the spindle, and both cutters must be set to cut in one track, if good work is wanted.

These machines can be used for a great number of jobs such as bevelling, chamfering, rebating, jointing, and so on, with or without stops. The newer machines allow also for the mounting of moulding cutters on one end of the spindle.

After surfacing comes the *planer* or *thicknesser*, and the above remarks on the cutters of the surfacing machine apply with equal force to the cutters of the planer, although some of these machines still carry the square block, which

is allowed because they are power-fed. There are usually three rates of speed for feeding the timber to the cutters, while the cutter spindle makes approximately 3,600 r.p.m. The two rollers of the table should be set 'a little flush' to prevent the timber sticking in the machine, whilst the pressure bars and feed rollers must be carefully set to prevent bad planing and to avoid accidents. In large shops where four, five, and six cutter machines are used for planing and moulding, all the remarks made above apply to these machines in greater or lesser degree.

From the planer, the pieces of timber pass to the *spindle moulder* to be grooved, moulded, chamfered, and the like; in fact in the hands of a skilful operator the uses of this machine are innumerable. There are three types of spindle-heads used in this country, namely:

First, the *square block*, carrying the hard steel cutter, of which any number may be used. This is a splendid head for long runs of material, worked off the fence, the speed of the head being about 4,000 r.p.m. The cutters are not ground to the exact shape of the drawn design to be worked, but must be sharpened in exactly the same way as the surfacing machine cutters. This spindle-head is used most in the Building Trades.

The second, namely, the *slotted collars*, are a pair of slotted washers carrying two cutters in balance and equal in width—both being points which require exactness. The cutters are hard and treated in much the same way as those on the square-block, except that the mouldings and shapes can be worked without the use of the fence or ring-fence, and can be moulded right off the spindle; the speed is about 6,000 r.p.m.

The third is called the *French head*. It is doubtful whether it originated in France or whether a man named French invented it. Both are mentioned. This is a slotted spindle which will carry only one cutter, ground true to design, of soft steel, though the steel must be of good quality to retain its turned edge. The cutters are honed until quite sharp, then turned with a steel burnisher, until the edge cuts like a steel scraper. For small runs and quick changes this head wants some beating, and the cutter cuts with and across the grain with equal facility. It is very largely used in London and in all furniture and motor body trades.

Quite a book could be written on what these spindles can do, with the aid of templates and jigs, and also on the care, setting, grinding, balancing, hardening, and tempering of the cutters.

The *small band saw* is the last to be mentioned in this article. It is a valuable machine for cutting curves and the like, its uses being only limited by the operator. The saws need great care to prevent breakages, as well as careful adjustment on the wheels, with a good back-thrust washer to prevent case-hardening at the back edge of the saw.

In woodworking several other machines are necessary and important, such as the *overhead-spindle*, the *recessor*, the *stair-stringers*, the *driller*, and the *borer*, as well as the *jig-saw* and the *dimension saw*, the *dovetail machine*, the

chain and hollow chisel morticing machine and the *tenoning machine*, the last two of which cannot be dispensed with in any modern machine shop working for the Building Trade. On these the writer hopes to be able to contribute another article at some future occasion. At present, if he has been able to create an interest in this branch of the trade, the time taken in writing this article will not have been wasted. In conclusion, one piece of advice is given, namely, do not trust machines to *any* Tom, Dick, or Harry. Wood machines have a conscience, and for real good work require the best brains in the same way as other skilled trades do, and perhaps more.

BIOLOGY AND CONTROL OF HYLOBIUS ABIETIS

BY J. W. MUNRO

PART II[1]

FACTORS INFLUENCING THE NUMBERS OF HYLOBIUS

THE chief factors regulating the increase of animals under natural conditions are climate, soil conditions, food supply, and natural enemies such as parasites and diseases. While it has not been possible to study any of these factors in relation to *Hylobius* by strict experimental methods, my observations have been made over a sufficiently long period, and over a sufficient number of different localities, to permit of a general discussion as to which factors are the more important in regulating the numbers of *Hylobius*.

The climate affects *Hylobius* both directly and indirectly. Directly it affects the dates of appearance of the adult weevil in spring, the number of broods reared, and the rate of development of these broods, so that in general the rate of reproduction in northern districts is slower than in southern districts. Because of the sheltered habitat of the weevil larvae, and because adult beetles rapidly retire into the soil on a fall in temperature, severe cold has no catastrophic effect on *Hylobius*, and at most merely slows down rate of development. I have frequently, as at Montreatmont Muir, found *Hylobius* larvae lying in their tunnels in the bark surrounded by ice arising from the frozen water in the sodden bark, and these larvae thawed out and survived unharmed. Moreover, the majority of *Hylobius* larvae in an area occur well below the depth to which the soil is ordinarily frozen in this country.

Indirectly climate affects the increase of *Hylobius* by its effects on the weevil's breeding-ground. In Scotland and in the north of England pine stumps and roots normally serve as breeding-ground for four or even five years. In the south of England stumps and roots dry up more rapidly, and rarely serve as breeding-ground for more than three years. Larch stumps and roots are, in Scotland, seldom used as breeding-ground for three or even four years after felling, but in England they are utilized by the weevil within a year of felling, as happens in mixed pine and larch woods in the Forest of Dean.

In the west of Scotland, with its more humid climate, and to a less extent in the west of England, because the pine is not so important there as a forest tree, the growth of such fungi as *Armillaria mellea* and *Fomes annosus* on pine stumps frequently renders them unsuitable as breeding-ground for *Hylobius* in the second or third year after felling.

Snow-storms are in some parts of Scotland of considerable importance in relation to the increase of *Hylobius*, because pine branches over-burdened with frozen snow crash to the ground and, becoming partially embedded in the soil, form an important breeding-ground of the weevil in standing woods.

[1] Part I appeared in *Forestry*, vol. ii, pp. 31–9.

In general the effect of climate on *Hylobius* in this country is unimportant from a practical point of view. While the warmer climate of the south of England directly increases the rates of development and reproduction of the weevil, its indirect effects in drying up the soil, stumps, and roots tends to cancel the direct effects. The same holds true when the eastern and western districts of Scotland are compared, for while the milder climate of the west does not retard the weevil's activities as the frosts and cold winds of the east do, the rate of decay of stumps and roots in the west is more rapid than in the east. For these reasons the climatic factor is of secondary or even minor importance, as it affects the increase in numbers and outbreaks of *Hylobius*.

Soil conditions affect *Hylobius* mainly indirectly. They are an important factor regulating the distribution and growth of the Scots pine, the weevil's chief host. They affect the period during which stumps and roots are habitable by the weevil, but as this factor is also governed by climate it has no marked effect in general.

Of the insects and other animals associated with *Hylobius* only a few of them have any appreciable effect on its numbers. Of insects other than parasites and predators associated with *Hylobius*, only one enters into serious competition with it for breeding-ground, and this only to a very small extent. In the Spey district, in Moray and Inverness, the Grey Rhagium, *Harpium inquisitor* L. (*Rhagium indagator* Gyll. of Fowler's British Coleoptera) frequently utilizes the upper regions of the pine stump and larger roots, to the complete exclusion of *Hylobius*. Of the many other insects associated with the weevil, such as the *Hylurgops* and *Hylastes* bark-beetles, the *Pissodes* weevils and the longicorn bettles *Rhagium bi-fasciatum* and *Asemum striatum*, none are of any importance as affecting its increase in numbers, except that in very dry years in the south of England, *Asemum striatum* hastens the drying up of the stumps.

Of the part played by mammals and reptiles as enemies of *Hylobius* almost nothing is known. Grohmann (2) claims as one of the benefits of his special traps that they afford a harbour for blind-worms and lizards, which he implies are enemies of *Hylobius*, but he gives no definite evidence that *Hylobius* is actually preyed on by these reptiles.

With regard to birds our knowledge is little better. Escherich (1) lists the rook, carrion crow, hooded crow, magpie, jay, nutcracker, roller, starling, nightjar, black grouse, and woodpecker as enemies of *Hylobius*. Mr. McEwen, formerly head forester of one of the Forestry Commission areas in Banffshire, has recorded his finding the crop of a curlew crammed with *Hylobius* weevils. This record, like such records by Eckstein and Baer as Escherich quotes (loc. cit.), gives us very little information. *Hylobius* is certainly not the usual food of the curlew, and Mr. McEwen's record is chiefly of interest as showing that the curlew will inhabit and feed in felled areas, and, as I have found, will frequently nest in them until the new plantations close canopy.

With regard to woodpeckers, which are so generally referred to in the forest protection text-books as enemies of *Hylobius*, it is worth noting that the barred and the spotted woodpeckers are tree-top dwellers, and that even in England,

where it is more common than in Scotland, the green woodpecker is a haunter of park lands and meadows near woods, where it can be observed feeding in ant-hills. In my experience of *Hylobius* I have never seen a single stump harbouring that weevil which showed evidence of woodpecker attacks, and the only stumps of pine I have seen attacked by woodpecker were too dried and decayed to harbour *Hylobius*, and were inhabited only by the larvae of the longicorn beetle *Asemum striatum*. It must, therefore, be concluded that birds are of minor importance in regulating the number of *Hylobius*.

The only important enemies of *Hylobius* are the parasitic insects, of which in this country a braconid wasp is the most important. The identity of this braconid is still in doubt. I first obtained it in 1913 and in 1914 sent specimens to Dr. Szeplegeti of Buda-Pesth for identification. Probably because of the war I heard no more of them. In 1920 I submitted specimens to Dr. Waterston, of the Natural History Department of the British Museum, but some were mislaid and the remainder were males, and Dr. Waterston was unable to identify them with certainty. The species is closely allied to *Bracon hylobii* Ratz., and Escherich refers to it as *Bracon hybolii*, but on what grounds I do not know.

This Bracon species (Munro, 1917) lives as an ecto-parasite of the *Hylobius* larva and under natural conditions will destroy 30 per cent. of the larvae in a locality. It must therefore serve as quite a considerable check on the increase of the weevil. Another parasite which I have found only on two occasions is the Ichneumonid, *Ephialtes tuberculatus*.

Of insects predacious on *Hylobius* larvae in this country little is known. The larvae of the 'ant-beetle', *Thanasimus formicarius*, is occasionally found in the larval tunnels and pupal beds, but is more frequently found in the regions of pine stumps which harbour *Hylastes* larvae and beetles. Certain Nitidulid beetles, *Rhizophagus* species, *Pityophagus ferrugineus*, and *Glischrochilus* species occur in the larval tunnels, but it is doubtful if they have any considerable effect in destroying *Hylobius* larvae, although they do destroy the eggs and young larvae of the bark-beetles. Numerous Carabid beetles, and a few Elaterid beetles are recorded by continental authors as preying on *Hylobius*, but I have no evidence that beetles of these families or their larvae really attack *Hylobius* in this country. In general, predacious insects, because of their more active habits and wide range of food, are less easily assessed as checks than are the parasite or 'parasitoid' insects which are more specific in their feeding habits. Until more accurate quantitative studies can be made of the relationship of the insects, predacious or parasitic, on *Hylobius* to their host, the value of the biotic factor as a check on *Hylobius* can be assessed only in a very general way, but the impression remains that the biotic factor is of secondary importance.

Of the micro-organisms causing disease in *Hylobius*, little is known. The fungus *Isaria densa* Link and Picard, is in some seasons destructive to large numbers of the beetles and occasionally also to their larvae, but I have never seen any other epidemic disease in *Hylobius*, and it is probable that such epidemics are of rare occurrence and minor importance.

The most important factor influencing the increase of *Hylobius* is the food supply, not of the adults only, but of the larvae also—that is to say, the supply of food and breeding-ground. This agency is alone sufficient to account for the outbreaks of *Hylobius* so frequently experienced by the forester, and in importance it far outweighs such agencies as climate and natural enemies.

Proof of this can be seen by examining the figures showing the numbers of weevils trapped on a felled area in successive years after felling, or by observing the increased number of larvae found in the stumps.

Hylobius, in common with many wood-feeding insects, is dependent for breeding-ground on trees reduced to an almost pathological condition, resulting from drought, fungus attack, or injury, and its numbers occurring in standing woods is regulated by the number and size of trees in that peculiar condition available in the area.

Buchner's recent summary of our knowledge of symbiosis in wood-feeding insects confirms this hypothesis, and if the 'pilz spritzen' which he figures as occurring in the reproductive organs of *Hylobius* are really fungus reservoirs, as he suggests, it is almost certain that *Hylobius* needs, for the successful establishment of its broods, conditions in the tree or its roots which are favourable to the development of the fungal symbiont, which the possession by *Hylobius* of these fungus reservoirs implies.

Although confirmation of this interesting possibility is wanting, it is still the case that *Hylobius* finds only more or less limited opportunities for breeding in standing woods, and that in such woods its numbers vary little from year to year. When thinnings are carried out, suitable breeding-ground is provided for the weevil, but its increased numbers are unobserved, because the weevils do not make their presence known, as they do in the replanted felled area, but feed on the young twigs and branches of the trees, causing no evident injury to them.

When felling takes place the breeding-ground of the weevil is enormously increased, and, as has been shown in the first part of this article, the weevil rapidly increases in numbers until it becomes a menace to replanting. This aspect of the weevil problem has long been recognized by foresters, and nearly all the control measures as practised against *Hylobius* aim at a reduction of the breeding-ground, either by removal of the stumps, by charring them, or by treating them with creosote, or aim at trapping the weevils on the felled area itself.

The weak point in all these control measures is that they are taken too late, and almost always after the weevil has made such headway as to make its control almost prohibitively costly. The real time for controlling *Hylobius* is to control it in the woods before they are felled—that is to say, during two or three years before felling is to take place. At such times the weevil population is small and traps consisting of short sections of pine stem or branch partly submerged in the soil or humus are especially attractive. Experimental work to assess the practical value of this method of control was begun by me in Hawkhill Enclosure in the New Forest in 1925, and the results up to 1927

were sufficiently hopeful to justify further experimental work. The chief difficulty in employing the method is to ensure organization and planning of fellings, but if there is any virtue in organized forestry, it ought surely to be possible to foresee fellings two or three years ahead, and the forest officer or forester who cannot anticipate his operations does not deserve consideration.

The advantage of trapping *Hylobius* in woods two or three years before felling are firstly, that the weevils occur in small numbers so that fewer traps are necessary to attract them, secondly, that even a small reduction in their numbers has an effect very much greater than a similar reduction would have once an outbreak has made headway, and finally, that its cost is very much less. The method is based on sound biological data and is one well worthy of serious trial both experimentally and in actual practice. It involves but little labour and very little expense in trap material.

In advocating further work on early prevention of weevil outbreaks, it may be well to point out that the old methods of uprooting, creosoting, or burying stumps, are useless, that protective sprays on young plants are all but valueless, and that while trapping on the felled area can be effective, it is very costly. The much advocated system of delay in replanting of the felled area has nothing to recommend it, and may result in serious deterioration of the forest soil, which in the end may prove as great a cause of loss as the weevil damage it is intended to evade.

REFERENCES

(1) Escherich, K.: *Forstinsekten Mitteleuropas*, Band 4, Berlin 1923. (Full bibliography of *Hylobius* up to 1922.)
(2) Grohmann, W.: *Tharandter Forstliches Jahrbuch.* Tharandt, 1913.
(3) Munro, J. W.: *Proc. Roy. Soc. Edinb.*, xxvi, Part III, 1917.

REVIEWS

Recent Research on the Root Systems of Trees.

A Note by R. N. Aldrich-Blake

EXTENSIVE investigations of the root systems of forest trees have been stimulated in recent years by an increasing recognition of the value to silviculture of a knowledge of the specific rooting habits of important forest trees, and of the modifications induced therein by variations in soil conditions. In its dual rôle as an absorbent of water and salts and as an anchor, the root system is fully as important as the more easily and therefore more thoroughly investigated shoot system in controlling the rate of increment of forest stands. It is now well recognized that root competition may be as severe as the competition between the crowns of a stand, and a knowledge of root development is therefore a useful guide to rational thinning, valuable in explaining and avoiding storm and drought injury, and in the prosecution of regeneration operations.

Hesselink (3) and Schreiber (8), in their studies of Scots and Austrian pine and larch and spruce respectively, were concerned only with the root systems of young plants. Most of Liese's (7) work also was confined to a morphological and anatomical study of roots of young Scots pine, though he included some observations on roots of older trees. The remaining papers considered describe studies on the rooting habits of trees from an age of about 10 years to maturity. Hilf (4) excavated roots of spruce and beech on sandy loams, and of Scots pine on sands, gravels, and chalk. Vater (9) published records collected by several of his students at Tharandt on the rooting habits of the same three species on a variety of soils. Groth's (2) research on Douglas fir was stimulated by the severe storm damage suffered by this species in Germany. The three Finnish workers were principally concerned with roots of Scots pine, though they included scattered observations on spruce and birch. Aaltonen's (1) excavations were on sandy soils, Kokkonen's (5) on drained peaty moorlands in which the water-table stood about a foot below the surface, while Laitakari's (6) extensive observations were made on a large variety of soils.

The main impression derived from a perusal of these records is that the root system is far more plastic than the subaerial portions of a tree. It is hardly possible to define a normal rooting habit for any species. At present we have insufficient experimental data to analyse the influence of the several inherent and environmental factors which control the rooting habit of a mature forest tree, and we can only build up conjectures based on circumstantial evidence from field observations.

All European forest trees possess a strongly positively geotropic radicle in the early seedling stage; and this may persist as a well-developed tap-root, or sooner or later it may be suppressed or die back. Such suppression or death is most frequent and earliest in spruce, and would appear to be almost inherent for this species: yet the occasional occurrence of a tap-rooted spruce indicates that the true inheritance of the spruce radicle may be an unusually high oxygen requirement, or extreme intolerance of atmospheres rich in CO_2. An extension to our common forest species of experimental work along the lines of Cannon's studies on the influence of soil atmospheres on the rate of root growth is desirable in this connexion.

The number of protoxylem strands in the radicle controls the initial orientation of the secondary roots borne thereon, since daughter-roots are produced endogenously

from the pericycle opposite these strands. Liese (7) found that the radicles of Scots pine seedlings are tetrarch or triarch at the root-collar, but a reduction to diarchy occurs at varying depths, and thereafter but two rows of secondary roots are produced, and the soil is less well permeated by secondary roots than in the region where the radicle has more protoxylem strands. In all species roots of pericyclic origin are diarch at the point of attachment, but an augmentation of the number of xylem strands occurs normally in many species, though never in the Scots pine.

More important than the original orientation of daughter-roots is their density on their parent-root. Some measures of this have been obtained by Schreiber (8) and Hesselink (3), who measured the total length of root systems and counted the number of root-tips. Their 'root quotient' is the total length of the root system in mm. divided by the number of root-tips; and a low root quotient therefore indicates dense, a high root quotient sparse branching. The root quotient is the best criterion of absorbing efficiency of a root system which can be obtained from purely morphological investigation. It naturally varies with age and external circumstances, so that the results of these two workers cannot be compared. Schreiber (8) found that larch had a higher root quotient than spruce, while Hesselink (3) found that this quotient was rather higher for Austrian than for Scots pine.

In passing on to deal with the root systems of older trees it is convenient to deal separately with the horizontal, the scattered vertical, and the central vertical portions thereof.

In the majority of species the more superficial secondary roots form the skeleton of the horizontal root system, but in spruce on moist soils these are reinforced and may ultimately even be replaced by adventitious roots from the base of the stem. These horizontal roots appear to be little influenced by gravity, or else this force is less potent than aerotropism, the tendency to direct their course to regions of high oxygen content; for in most species they grow obliquely downwards to a depth dependent on species and soil conditions, and thereafter pursue a more or less horizontal course. In the case of the beech excavated by Hilf (4), however, they pursued a very up and down course in the mineral soil between depths of 4 inches and 2 feet. Laitakari (6) has shown conclusively that the horizontal root system of spruce is shallower than that of Scots pine on similar soils; for while the average depth of this portion of the root system of pine varied between 3 inches and 10 inches, that of spruce seldom exceeded $3\frac{1}{2}$ inches. Hilf (4) discusses the consolidating effect on the mineral soil of a superficial mat of spruce roots.

As regards the extent of the horizontal root system it appears probable from Hilf's (4) data that this is absolutely less in beech than in pine and spruce. The matter cannot, however, be clinched without excavating roots of these species under more comparable conditions. It does, however, appear certain that the horizontal root system of beech is generally confined to the area beneath the crown, while there is ample evidence from several of these papers that roots of spruce and pine extend far beyond this limit; and thus much of the root activity of these trees takes place beneath the crowns of neighbours several trees distant. Thus in this sense the beech has a more intensive rooting habit than pine and spruce; but the terms extensive and intensive are generally used in a different sense, namely, to denote the degree to which individual roots are specialized as pioneers of indefinite growth and sucking roots of ephemeral existence. In this sense all three species are intensive, as opposed to ash and alder, in which there is much less specialization. It remains to be proved how far this specialization of sucking roots is bound up with mycorrhizal infection.

Only in the case of Scots pine have we sufficient data to discuss the development of the horizontal root system throughout the life of the tree. Laitakari (6) showed that the rate of extension of this portion of the root system increased to a maximum fairly early in life, and thereafter declined. Thus during the first fifty years of a tree's life the main horizontal roots may grow as much as a foot per annum: yet the longest horizontal root ever recorded, from a tree 135 years old, was only 75 feet. Vater (9) even maintains that the horizontal root system is more widespread in youth than later, owing to extensive injury and death. Liese (7), however, claims that the root system of pine may be improved by pruning, provided the roots be cleanly cut; for thus treated they callus over at all periods of the year, and regenerate freely in summer, often producing the useful triarch or tetrarch roots in place of the original diarch ones. Laitakari (6) measured the density of the horizontal root system by finding the length of root system per unit area of ground permeated thereby; and he found that density increased with age: that is to say, that in youth a pine explores a large area with its horizontal roots, while later in life it exploits the area covered more thoroughly.

Most of the workers referred to here maintain that poor sandy soils lead to great growth in length with poor branching, while richer soils induce copious branching. The value to the tree of such response is evident, but causal explanations have not been produced, nor do such records agree well with all the results of more closely controlled experiments.

The old belief that the root system is most strongly developed on that side on which the crown is best developed does not always hold good. Crown and root system appear to be influenced independently by their respective environments.

In all the species here considered the majority of the branches of the superficial secondary roots grow on at much the same depth as their parent-roots, with the result that the vertical extent of the horizontal root system is fairly narrow. But wherever conditions are suitable for the development of a deep root system we find that all species, spruce included, produce vertically descending 'sinkers' on the horizontal root system at varying distances from the bole. Those near the bole replace or reinforce the tap-root, forming the central vertical root system; those more distant must greatly increase the anchoring power of the root system as a whole. We have no experimental work to show whether these sinkers possess tropic reactions to environment different to those of other roots. Laitakari (6), however, notes that the scattered vertical roots of pine are most frequent in the decaying stumps of a previous generation of trees, an observation which indicates that such specialization is improbable. Further, it sometimes occurs that the horizontal roots change direction and themselves become sinkers. Beech, with its comparatively deep-going horizontal root system, differs from other species in that many of the branches from this portion of the root system grow vertically or obliquely upwards to the humus layer, attracted thereto perhaps by chemotropism. In the humus layer these ascending branches branch very freely and intensively. Hilf (4) showed that more than three-quarters of the fine roots lay in the humus layer, which was 4 inches thick.

The central vertical root system finally demands attention. In deep, well-aerated soils the penetration of the tap-root may be considerable, and its growth in no way distorted. But it frequently occurs that continuous downward growth is frustrated quite near the surface by an impermeable pan or a high water-table. Under these circumstances the tap-root dies back, persists to that depth, but grows no farther, or else, turning through a right angle, pursues a horizontal course. Bent tap-roots were frequently found by Kokkonen (5) in his excavations of pine roots on moors where the

water-table stood about a foot below the surface. Without anatomical evidence it is impossible to say whether the horizontally growing portions of these roots were continuations of the original radicle, or secondary roots produced thereby. The present writer has, however, witnessed a clear case in which other forces proved stronger than geotropism in controlling the direction of the radicle. In a humus-filled crevice between the logs forming the roadway of a rustic bridge in Corsica he excavated the roots of a young Corsican pine, and found that the radicle itself pursued a horizontal course on reaching the lower side of the bridge, hydrotropism, chemotropism, or both these forces together, evidently proving stronger than geotropism.

In spruce past the seedling stage tap-roots are rarely seen, but records of their occurrence are not entirely lacking. In Douglas fir it appears to be unusual to find a tap-root in trees 20 years old. Beech has a pronounced tap-root up to an age of about 50 years, but thereafter this dwindles and is replaced by a heart-root system composed of vertical and slightly oblique sinkers and their branches. The tap-root of pine may persist throughout life, but it is generally strongly reinforced by other roots, and usually supplanted thereby.

The form of the central vertical root system, and the depth to which it penetrates, depends on external conditions, and most frequently on the soil aeration. In all the species here considered this portion of the root system may be completely absent if the penetration of roots be prevented by an impermeable pan or a high water-table. It is generally supposed that a deep central vertical root system is never formed by spruce, but this belief has been founded on observations of root systems of wind-thrown trees; and such damage is naturally confined to localities where the spruce is able to produce only a superficial root system, on account of a high water-table or the poor aeration of all but the superficial layers of soil. Vater (9) found that on loose stony soils old beech and pine had heart-roots extending to a depth of three feet, while the heart-roots of spruce extended somewhat deeper. Hilf noted that spruce grown on normally moist sites suffered severely during the 1911 drought, while plantations on normally drier sites were unharmed, owing to the comparatively great depth of the root system. Groth (2) assessed the aeration of the soil by mechanical analyses, and showed that green Douglas fir forms only a horizontal root system on poorly aerated soils, and is there subject to considerable wind and snow damage; while on well-aerated soils a good heart-root is produced and the tree is wind-firm. He found that close planting and neglect of thinnings tend to the suppression of the heart-root, and therefore advocated wide planting and frequent thinning, especially on poorly aerated soils.

REFERENCES

(1) Aaltonen: 'Über die Ausbreitung und den Reichtum der Baumwurzeln in den Heidewäldern Lapplands.' *Acta Forest. Fenn.*, 1920, 14, pp. 1–55.

(2) Groth: 'Die Wurzelbildung der Douglasie und ihr Einfluss auf die Sturm- und Schneefestigkeit dieser Holzart.' *Allg. Forst- und Jagd-Zeit.*, 1927, pp. 186–205, 217–231, 268–85.

(3) Hesselink: 'Een en ander over de wortelontwikkeling van den Grove Den en den Oostenrijksche Den.' *Med. van het Rijksboschbouwproefstation*, 1926, Deel 2, Af. 3.

(4) Hilf: *Wurzelstudien an Waldbäumen*, Schaper, Hannover, 1927.

(5) Kokkonen: 'Beobachtungen über das Wurzelsystem der Kiefer in Moorböden.' *Acta Forest. Fenn.*, 1923, 25, pp. 1–20.

(6) Laitakari: 'The Root System of Pine, *P. Silvestris*.' Summary in English. *Acta Forest. Fenn.*, 1927, 33.

(7) Liese: 'Beiträge zur Kenntniss des Wurzelsystems der Kiefer.' *Zeit. f. Forst- und Jagdw.*, 1926, pp. 129–81.

(8) Schreiber: 'Zur Frage "Saat oder Pflanzung der Lärche". Teil 2. Beiträge zur Kenntniss des Wurzelsystems der Lärche und der Fichte.' *Centr. f. das ges. Forstw.*, 1926, pp. 1–14, 78–103, 147–62.

(9) Vater: 'Die Bewurzelung der Kiefer, Fichte, und Buche.' *Thar. Forstl. Jahrb.*, 1927, pp. 66–85.

Recent Research on Stem Form.

A Note by James Macdonald

FOREST mensuration, which in recent years has been attracting a good deal of attention, has now reached an interesting stage in its development. The work that has been going on, chiefly in Scandinavia and in North America, has been concerned almost solely with the problems arising out of the form of the stem in coniferous trees. It is naturally of two kinds: on the one hand there have been what may be called the fundamental researches, that is to say, researches into the causes underlying the peculiarities of form which trees exhibit; and on the other hand there have been the investigations which have dealt with the practical application of the various theories to mensuration in the forest. Of the papers noticed here, Tirén's 'Einige Untersuchungen über die Schaftform' belongs to the class of fundamental researches; the other papers belong more properly to the second class. The structure of the stem of a tree has long been the object of speculation. More than thirty years ago, Metzger (10) put forward the theory that the stem is built up in such a manner as to offer, with the minimum of material, the strongest resistance to the pressure of the wind. On the assumption that the stem is homogeneous throughout its length, this theory requires it to have the form of a cubical paraboloid, the top of which is situated at the point where the wind pressure is considered to be concentrated.

More recently, Hohenadl (3) has suggested that the stem of a tree is constructed not in order to resist the bending effect of wind pressure on the crown so much as to support its own weight and the weight of the crown, and he has calculated that the girth at any point on the stem is dependent on the weight of the tree above that point and also on the strength of the material of which the stem at that point is composed.

Both theories are touched on in Tirén's first paper in so far as each of the mechanical forces to which the tree is subject is discussed. Tirén mentions, without discussing them, theories such as Jaccard's (6) transpiration theory, and indicates that the mechanistic theories will take us only part of the way to the solution of the problem of stem form, a problem which, in the last analysis, is physiological. Such open-mindedness, though unusual in scientific works, is highly to be commended, but it gives an air of indefiniteness to the whole of the paper. The paper is divided into seven chapters. In the first three chapters the author discusses the main points of the wind-pressure hypothesis. These are, firstly, the wind velocity; secondly, the wind pressure on the crown; and, thirdly, the crown area exposed to the pressure of the wind. This ground has been largely covered already by the author in earlier publications (14) which are now well known, and Chapter I, in particular, is merely a *résumé* of earlier work. In chapter IV he gives an account of the properties of green wood that are of the greatest importance—strength, elasticity, specific gravity, and water-content. This chapter is based partly on the researches of Janka (7) and Wijkander (17), but also on the results, yet unpublished, of an investigation carried out officially in Sweden. Chapter V deals very thoroughly with the underlying mathematical theory, Chapter VI with an examination of two sample trees of Norway spruce, and Chapter VII with a detailed investigation

of stem form in dense crops of trees. The results unfortunately are not quite definite, but the paper, nevertheless, is worthy of the closest study on account of the ingenuity of the methods which it describes, the freshness of the treatment, and the candour of the presentation.

The other papers deal with the more practical questions of the taper of stems and the calculation of stem volumes. The study of the taper of trees was placed for the first time on a secure foundation by Tor Jonson (8) in Sweden, in his works published in 1910 and 1911. In order to express the form of a tree, he made use of a formula devised in 1903 by Höjer. This formula, now familiar, is expressed as follows:

$$\frac{d}{D} = C \log \frac{c+l}{l}$$

where D is the diameter at breast height, d the diameter at a distance l from the tip of the tree, while C and c are constants. These constants vary with the form-class. Jonson found that this equation agreed remarkably well with the form of Norway spruce as actually measured, but with Scots pine the agreement was bad, especially in the higher parts of the stem. In order to correct this, he introduced what he called a 'biologic constant', and his formula for Scots pine became

$$\frac{d}{D} = C \log \frac{c+l-2{\cdot}5}{c}.$$

With these equations as a basis, he prepared volume tables.

In 1925 Petterson (12) showed that the curve of the logarithmic function $y = \log x$ expressed the same relationship between the diameters as Höjer's equation when the top of the tree is located in the point $x = 1$ and the length of the tree along the x-axis. Proceeding, he developed his celebrated combination of curves as an expression of stem form. With the curve $y = \log x$ cutting the x-axis in the point $x = 1$, he combined a tangential curve which passed through the origin and met the logarithmic curve in the point $x = 4$ for pine and $x = 6$ for spruce. In this way, for pine, the tip of the tree was fixed in the origin, the uppermost part of the stem, from $x = 0$ to $x = 4$ was represented by the curve $y = 2 \log \left(1 - \frac{x}{4}\right)$ and the remaining part of the stem from $x = 4$ onwards, by the curve $y = \log x$. The different form-classes were obtained by varying the basal abscissa x. There was thus no need for a series of curves, one for each form-class, as all form-classes were represented by the same curve, and this was a great advance.

Working in the United States, Behre (1) in 1923 proposed the curve given by the equation $\frac{d}{D} = \frac{l}{a+bl}$ which represents a hyperbola. This has been found to correspond very closely to the actual taper of a wide variety of species not only in America but also in Great Britain. For each form-class with this equation, as with Höjer's, there is a separate pair of constants and a separate curve.

Tirén, in the second of the papers noticed here, puts forward yet another equation as representative of the form of the stem.

This is written as follows:

$$r = \log (x - \sqrt{1-x^2}) \text{ when } r \text{ is the radius.}$$

The tip of the stem in this case lies in the origin and the form depends on the basal abscissa x_b.

$$\text{The form-class } \phi = \frac{\log \frac{x_b}{2} + \sqrt{1 + \left(\frac{x_b}{2}\right)^2}}{\log (x_b + \sqrt{1 + {x_b}^2})}.$$

This formula has been tested by Tirén on Jonson's Scots pine material and on other pine material as well. The author found that, tested on this material, his curve gave satisfactory results. Compared with the other curves, in one case, Petterson's curve combination gave better results; in another, Johson's and Tirén's curves were better than both Petterson's and Behre's. The differences, however, were small. In his conclusion, Tirén makes the interesting statement that it is not yet possible to say definitely which of these curves is likely to give the best results. One of the curves may be better suited to the stem form in a certain district or on a certain soil, and it is by no means sure that the curve suited to the average stem form of a whole country is the best for every special case.

In the first of his papers, Petrini deals with the application of the various expressions for the stem form to the calculation of volumes. In addition to the four equations already mentioned he gives that for the paraboloid.

First of all, he made a comparative test of the equations on some of Petterson's pine material and found that all five corresponded quite well to the lower half of the stem, though the paraboloid gave values which were too small throughout. In the upper part of the stem the differences were, however, more pronounced. The paraboloid gave far too large a figure, and Höjer's equation did not give too satisfactory a result. Petterson's and Tirén's equations were the best, but Behre's was almost equally good. Petrini then goes on to discuss a formula for calculating the volume of a stem—a formula which he put forward in 1926 (11). This formula, derived from Höjer's equation for the stem curve, is expressed as follows: $V = 0{\cdot}73\ G_{0{\cdot}34}\ H$ when $G_{0{\cdot}34}$ is the sectional area at a point 34 per cent. of the length of the stem measured from below upwards. The use of such a formula, however, is circumscribed by the necessity for the elimination of the root-swelling. The formula, when tested on suitable material, was found to give results quite satisfactory and better than those obtained with formulae deduced from the other equations. Further work on the applicability of this formula is being carried on by Petrini, and special attention is being devoted to the problems involved in the calculation of the volumes of small trees. This problem is touched on in Petrini's second paper, which deals with the errors involved in cubing a stem in sections. The author shows that this process is always charged with a negative error and that the errors are greatest in the poorest form-classes. The most difficult trees to measure accurately are young trees of low form-class.

Petrini recommends that trees of less than 20 metres in length should be measured in one-metre sections. For longer trees, three-metre sections may safely be used. For trees of less than 10 metres in length, even one-metre sections do not give satisfactory results.

REFERENCES

Primary References

Tirén, Lars: *Einige Untersuchungen über die Schaftform.*' *Medd. f. Statens Skogsförsöksanst*, 1928

—— *Tillfrågan om tallstammens avsmalning och volymberäkning.*' Ibid. 1928

Petrini, Sven: *En närmeformel för kuberung av träd.*' Ibid. 1928

—— *Sektionskuberingens noggrannhet.*' Ibid. 1928

Secondary References

(1) Behre, C. E.: 'Preliminary notes on Studies of Tree Form.' *Journal of Forestry*, Washington, 1923.
(2) —— 'Form-Class Taper Curves and Volume Tables and their Application.' *Journal of Agricultural Research*, Washington, October, 1927.
(3) Hohenadl, W.: 'Neue Grundlagen der Holzmessung.' *Forstw. Centralblatt*, 1922.
(4) —— 'Der Aufbau der Baumschäfte.' *Forstw. Centralblatt*, 1924.
(5) —— 'Ziele und Methoden der forstlichen Forschung . . .' *Forstw. Centralblatt*, 1924.
(6) Jaccard, Paul: *Nouvelles recherches sur l'accroissement en épaisseur des arbres.* Lausanne and Geneva, 1919.
(7) Janka, G.: 'Untersuchungen über die Elastizität und Festigkeit etc.' *Mitt. d. forstl. Versuchsanst. Oesterreichs*, 1900–4.
(8) Jonson, Tor: 'Taxatoriska undersökningar öfver Skogsträdens Form. I. Granens Stamform.' *Skogsvårdsför. Tidskr.*, 1910.
(9) —— 'Taxatoriska Undersökningar öfver Skogsträdens Form. II Tallens Stamform.' *Skogsvårdsför Tidskr.*, 1911.
(10) Metzger, C.: 'Der Wind als massgebender Faktor für das Wachstum der Bäume.' *Münchener forstliche Hefte*, Berlin, 1893.
(11) Petrini, Sven: 'Formeln für Stammkubierung.' *Tharandt. Forstl. Jahrb.*, 1926.
(12) Petterson, Henrik: 'Sambandet mellan kronan och stamformen.' *Skogsv. fören. Tidskr.*, 1925.
(13) —— 'Studien över stamformen.' *Medd. f. Statens Skogsförsöksanst.*, 1926.
(14) Tirén, Lars: 'Om en undersökning av vindhastigheten i skogsbestånd.' *Skogsv. fören Tidskr.*, 1924.
(15) —— 'Några undersökningar över stamformen.' *Skogsv. fören. Tidskr.*, 1926.
(16) —— 'Om barrytans storlek hos tall bestånd.' *Medd. f. Statens Skogsförsöksanst.*, 1926.
(17) Wijkander, A.: *Untersuchung der Festigkeitseigenschaften schwedischer Holzarten.* Göteborg, 1887.

Recent Research on Forest Drainage.

A Note by H. M. Steven

IT is difficult for the present generation in this country to realize the extensive drainage and land reclamation work which has been carried out in Britain by our ancestors, ever since settled cultivation began in Roman times or earlier. Much of the agricultural land of to-day was once carved out of forest, bog, and swamp. The task is far from being finished, especially on the peat lands of the more mountainous regions, such as in Wales, the Pennines, the Cheviots, and the Highlands of Scotland, particularly in the West Highlands, and successful afforestation in such places will only be possible if well conceived and systematic drainage is first carried out, and subsequently maintained. In the broad-leaved woodlands on the heavy soils of the South and Midlands of England, there are also important drainage problems.

An important paper on forest drainage, particularly in relation to peat areas, has recently appeared, and deserves the attention of all foresters in this country who have to deal with peat. It is by Malmström (2), one of the Swedish investigators, who has studied the subject closely during the past few years. In this paper the history of forest drainage in Sweden, the theoretical basis of drainage, and the application of the latter to practice are all discussed.

Malmström points out that water in peat ground occurs in two different forms: partly as bound water, and partly as free water. By bound water is meant that which is more or less firmly adhesive to the soil particles, and includes water which is chemically

bound, i.e. a component of the actual peat or mud substance; water which is colloid-chemically bound, i.e. water in a *gel*, and peat in its natural state consists to a considerable extent of *gels*; and capillary water which moves under the influence of capillary forces which act in the capillaries or small tubes which are numerous in slightly disintegrated peat. By pressure a considerable amount of the capillary water can be removed, but not the chemically or colloid-chemically bound. Free water includes the exposed or surface water; the ground water which rests on a more or less impermeable layer of the earth's crust, or in this situation moves under the influence of gravity; and percolating water which is moving downwards under the force of gravity to the ground water. Drainage only taps the free water because the chemically bound and the colloid-chemically bound cannot move, and the capillary water only to a small extent. Such bound water can only be removed by evaporation.

Malmström quotes earlier work which he did on the amount of water capillarily and colloid-chemically bound in different peat types. He found that seven- to nine-tenths of the entire volume of the peat mass consists of capillarily and colloid-chemically bound water, which can only be removed by evaporation, or in the case of capillary water in part by pressure. It is the undisintegrated peat types, such as the *Scirpus caespitosus-Sphagnum* peat, and the *Sphagnum fuscum* (a variety of *Sph. acutifolium* Ehrh.) peat which bind most per unit weight of peat, and the strongly disintegrated mud peats which bind least.

Coming to ground water it is shown that its movement in peat is often very slow. The mud peats are relatively impermeable to water compared with the undisintegrated peat types just mentioned, hence when, as often happens in Sweden as in this country, the upper layer of a peat is relatively undisintegrated and this rests on disintegrated mud-peat, the ground water really only exists in the upper porous peat-layer.

To successfully drain a peat area it is necessary to favourably alter the balance between the water feeding the peat area and the run-off and evaporation from it. The first step is to deal with the water flowing into the peat. This is usually relatively easy, but requires a careful study of the general topography, the structure and the permeability of the peat. The inflow of the water may be prevented by a ditch, or a direct outflow constructed. In most instances this is not enough, and the surface and ground water has to be tapped. The possibility of success in this depends on the nature of the peat. If the superficial layers are highly disintegrated and dense, and the water cannot percolate appreciably, surface water can be readily removed by relatively shallow drains. If the peat, although disintegrated, has a high capacity for absorption the task is more difficult. Finally, if the peat is porous and water-logged, while much ground water can be got out, this causes the sinking and compression of the peat and this then causes difficulties. Stress is laid on the importance of a high transpiring vegetation, such as a forest crop, in keeping a drainage system effective. In Britain, in regions of high rainfall, more intensive methods are necessary to secure a forest crop of many peat types. The method being followed is the application of the so-called Belgian system of drainage and turfing after the inflowing water has been dealt with. This has recently been discussed by the present writer (3).

A chapter is devoted by Malmström to the causes which inhibit tree growth on peat. They are lack of oxygen, insufficient nourishment, adverse climatic conditions, physical conditions unfavourable to tree-roots, and the existence of certain substances injurious to trees. The importance of aeration in relation to mycorrhiza is discussed and reference may be made to an article on this subject elsewhere in this journal. An interesting table is given after von Post and Granlund, showing the percentage of ash, percentage of

lime, and percentage of nitrogen in different peat types. This again stresses the poorness of *Sphagnum* peats.

From the practical point of view one of the most interesting parts of the paper deals with the classification of peat for the purposes of afforestation. As everywhere, importance is laid on the character of the ground vegetation, and particularly the presence of trees, certain bushes, and shrubs. For example, the presence on undrained peat of alder, spruce, and birch indicates that good forest production will be got after satisfactory drainage. On the other hand, experience has shown that peat which carries stunted Scots pine is much less suitable for afforestation. If the bogs are treeless, then the ground vegetation and degree of disintegration and porosity of the peat are used. The presence of *Carices* and *Eriophorum polystachion* on peat which is fairly well disintegrated up to the surface indicates the possibilities of good timber production after drainage. On the other hand, *Eriophorum vaginatum* or *Scirpus caespitosus* on more or less undisintegrated peat reflects much poorer chances of success. In this country we are now taking a more hopeful view of *E. vaginatum* types provided this species is associated with grasses, and intensive drainage is carried out.

Lukkala (1) has recently described the organization and methods of moor drainage in Finland. The most interesting point is the application of Cajander's forest types to this work. Tanttu (4) has worked out the outlines of the succession from bare moorland to the different forest types, and this is used to determine the possibilities of success before the work is taken on hand. For example, the poorest moor types turn into *Cladina* type, and the better moor types into the better forest types. Only when the forest type to be expected is the *Vaccinium* type or better is the quality considered to be suitable for drainage. The tracing of the succession from moor to forest in this country is practically impossible until we have crops on known types, but this is undoubtedly a line of research which may be expected to yield valuable results in future.

REFERENCES

1) O. J. Lukkala: 'Metsähallinnon suonkuivaustoiminnassa saavutettuja Kokemuksia sekä, Suunta viivoja suonkuivausta Koskevan Tutkimustjön Kehittämiseksi.' (Experience gained in moor draining by the Finnish State Service, and lines along which research work for moor draining should proceed.) *Silva Fennica*, 8, pp. 1–29, 1928 (English Summary).

(2) Carl Malmström: 'Våra Torfmarker ur Skogsdiknungssynpunkt.' (Our Peat Areas from the Point of View of Forest-draining.) *Reports of the Swedish Institute of Experimental Forestry*, 24, pp. 251–372, 1928 (English Summary).

(3) Steven: 'The Afforestation of Peat.' *Quart. Journ. Forestry*, January, 1929.

(4) A. Tanttu: 'Studien über die Aufforstungsfähigkeit der entwässerten Moore.' *Acta Forestalia Fennica*, v, 1919.

Foundations of Silviculture upon an Ecological Basis, Volume I, by James W. Toumey, M.A., F.D., Sc.D., John Wiley & Sons, Inc., New York, Chapman & Hall, Ltd., London, 1928. Price 20*s.* net.

A Review by H. M. Steven

PROFESSOR TOUMEY has taken an important place in the provision of literature in English for the teaching of silviculture, and we heartily welcome this new book, and recommend it to all foresters. This volume contains two parts, Part I, which deals with site factors, climatic, physiographic, and biotic, with chapters on the reaction of

forest vegetation on the site factors, and Part II, which deals with the forest. Another volume is contemplated dealing with the methods of investigating the site factors and forest vegetation, and relating one to the other.

Silviculturists have realized for some time that much greater attention must be given to the basic factors of climate, soil, and physiology, and that we will not secure a definite advance in silvicultural technique until we know much more about these basic factors, and base our technique on that knowledge. Much that is known about the subject is not generally accessible, hence a volume such as this is very useful both for teaching and general purposes.

A book such as this merits serious criticism. Professor Toumey, although he has stated many facts, has not succeeded conspicuously in articulating them. One does not lay down the book with a picture of the forest, as a whole, and also as the expression of the multitude of individual influences, within the tree, in the air, and in the soil. We believe that if only the forester could get such a picture, clearly and vividly, and realized that whatever he does in the forest sends a reverberation through it, we would be on the way to more rational silviculture. To produce such a picture is not easy, because the subject, or rather subjects, are now so large that it is difficult for any one man to focus them critically and lucidly. We suggest, however, that the foundations of silviculture should be developed in a different order than that adopted by the author. The climate and the site should be taken first, as Professor Toumey does, but a much more adequate presentation, particularly of soil, is necessary if a clear picture of its importance is to be given. Secondly, the physiology of the tree should be dealt with; this is the basis and should not be left to the end as is done in this volume. Thirdly, the physiology of the stand should be discussed, linking up all the threads into a picture of the living forest. This is forest ecology, in the rather wide sense of this somewhat nebulous term. To present the foundations of silviculture adequately will probably require three volumes instead of one, and this will be necessary at no distant date, but in the meantime, Professor Toumey's book fills an undoubted gap in our literature.

Engineering for Forest Rangers, by A. H. Lloyd, M.C., M.A., Oxford, at the Clarendon Press, 1929. Price 17*s.* 6*d.*

A Review by F. A. Leete

THE Foreword by Mr. H. W. A. Watson, Chief Conservator of Forests, Burma, is itself such a very good and appreciative review of the book, that it may well be quoted. 'The main desideratum of the textbook was that it should set forth the elementary principles of engineering in their application to forest work in a concise, practical, and common-sense manner, and in simple language. Mr. Lloyd has succeeded in fulfilling these requirements in a truly admirable manner. His book is concise, simple, practical, and sound. I am confident that its range of utility will not be restricted to the Forest Department in Burma for which it was primarily written. Its conciseness and simplicity should appeal not only to all agencies working timber in Burma, but to all those concerned with education and forest management or exploitation in the tropics.'

Mr. Lloyd is indeed to be congratulated. His book is excellent and may well be commended to all classes of foresters. I cannot help but feel regret that there was no such eminently sound and practical book to refer to in my own time.

The book is very well got up, and worthy of a place in any technical library. In this

respect the primary aim of the book seems to have been rather lost sight of. The book is far too big to be taken into camp, except on very special occasions. With thinner paper, and smaller type and pages it would have been half the size and much more portable.

As Mr. Lloyd remarks in the Preface, the book is a first effort, which may well lead to a more complete edition later on. May I offer the suggestion that, when this time comes, the possibility of a series of two or more pocket volumes might well be considered. The subjects dealt with would readily lend themselves to such a method of treatment.

NOTICES

The Forest Industry of Finland. W. E. Hiley, M.A. *Oxford Forestry Memoirs*, No. 8, 1928. The Clarendon Press, Oxford. Price 4*s*. 6*d*.

THIS memoir of thirty-nine pages touches on the whole field of Finnish forestry: the climate, soils, silviculture, felling and extraction, saw-mills, economics of management, &c.; although succinct, it is lucid, and considerable detail is marshalled in tables. The kernel of the memoir is the discussion on the economics of management, but the other subjects, although ancillary to this end, widens its appeal to all who are interested in the growing and utilization of timber.

The criterion of profitableness adopted is the financial yield, i.e. the rate of compound interest which, when applied to all expenditure and all income from the time when it is incurred or received, to the end of the rotation, exactly balances the two sides of the account. The most important conclusion arrived at is that rates of interest of 3·5 to 5 per cent. can be realized on the industry of forest management on average soils in South Finland, which is a high yield for Scots pine. This high financial yield appears due to the following reasons:

(*a*) The cost of living is little more than a half of what it is in England.
(*b*) Regeneration is obtained with ease.
(*c*) The cost of annual maintenance is very low.

There are ten photographs illustrating different aspects of the forestry of this the most important exporting country in Europe.

Aerial Survey in Relation to the Economic Development of new Countries with Special Reference to an Investigation carried out in Northern Rhodesia. R. Bourne, M.A. *Oxford Forestry Memoir*, No. 9, 1928. Clarendon Press, Oxford. Price 7*s*. 6*d*.

THIS memoir discusses the possibilities of aerial survey as an aid in making soil and vegetation surveys, and presents, both by tables and photographs, the results obtained by this method in Northern Rhodesia. The memoir consists of two sections, Part I, the general report, and Part II, the Solwezi-Nchanga Road Reconnaissance Survey.

Part I deals with such subjects as: the special value of aerial surveys for forest purposes; the need for scientific co-operation in reconnaissance surveys; the actual procedure, method of record, and inferences deduced; feasibility, cost, and potential value of aerial survey made under conditions such as prevail in Northern Rhodesia.

The author concludes that the possibilities of rapid methods of aerial survey in the economic development of the Empire, given certain conditions, have been fairly demonstrated.

Part II discusses, for the area surveyed, the vegetational types and the coincidence of general vegetational types with general soil colours and geological formation.

Forestry Commission Report on Census of Woodlands and Census of Production of Home-grown Timber, 1924. H.M. Stationery Office, 1928. Price 1*s.* 9*d.*

THIS report consists of two parts, the census of woodlands, and the census of home-grown timber production.

For the Census of Woodlands the latter were divided into two main categories: Economic or potentially productive, and uneconomic. The first category was divided into high forest—with 10-year age-classes—coppice and coppice with standards, scrub, and felled or devastated woods. The second category includes amenity woods, shelter belts, and park timbers. The total woodland area in Great Britain is 2,958,672 acres, of which 478,106 acres are bare of timber and included in the subsection 'felled or devastated'. Of the gross area 47·9 per cent. is high forest, 17·9 per cent. coppice and coppice with standards, 11·2 per cent. scrub, 16·1 felled or devastated, 6·9 per cent. uneconomic. The following are the percentages of woodland in the three countries: England 5·1 per cent., Wales 5 per cent., Scotland 5·6 per cent. Of the high forest 47·4 per cent. are conifers, 31·3 per cent. hardwoods, and the remainder mixed, conifers and hardwoods. The distribution of age-classes in the high forest is reasonably normal for conifers up to 80 years, but the reserves of mature coniferous timber is low, estimated at six months' supply. On the other hand, in hardwoods there is a very heavy deficit in the classes up to 40 years. The economic or potentially productive woodlands are estimated to contain in all about 2,262 million cubic feet of timber and pit-wood. During and immediately after the war, 450,000 acres were felled, giving approximately 1,000 million cubic feet.

Part II presents the data for the Census of Home-grown Timber Production for 1924. This is dealt with in four sections: Distribution of total woodland area, production of timber 1923–4 by types of woodland and by classes of material, miscellaneous produce, and number of persons employed in forestry operations. The total amount of timber felled or sold for felling in the year in question was 55,985,000 cubic feet, valued at £2,036,000. The average price per cubic foot of saw-mill timber size was for pine 6*d.*, larch 1*s.* 1*d.*, spruce 7*d.*, oak 1*s.* 6*d.*, beech 10*d.*, ash 1*s.* 10*d.*, elm 10½d. The number of persons in permanent or principal occupation in forestry operations was 19,220. Home production was 3·3 per cent. of the consumption of conifers, and 25·2 per cent. of hardwoods.

Growth and Yield of Conifers in Great Britain. *Forestry Commission Bulletin*, No. 10, 1928. H.M. Stationery Office. Price 4*s.*

THIS is Forestry Commission Bulletin No. 3 largely rewritten, and containing new matter.

Chapter I deals with the collection of the data and Chapter II gives a description in some detail of the methods used of measuring the sample plots, which consist of both temporary and permanent plots. Chapter III presents the methods of constructing the

yield tables. The special feature of interest is that the height attained at 50 years (a less age in the case of Japanese larch) is used as the basis for dividing into quality classes, the interval being 10 feet; thus for European larch 80 feet, 70 feet, 60 feet, &c., at 50 years. For each plot an age-height stem analysis was made which made this method possible; further, these analyses for each quality class were used to construct the form of age-height graph for that quality class. The tables of volume, girth, number of trees, &c., were obtained by the graphical relationships between height-volume, height-girth, &c. Chapter IV gives the yield tables for the different species. Those for Scots pine, European larch, and Norway spruce are as published in 1920. A complete table is now given for Douglas fir, a complete table for Quality Class I of Corsican pine, an age, height, number of stems, volume table for Sitka spruce, and a similar table up to 30 years for Japanese larch. Chapter V discusses the results and compares the tables with those of other countries, there being a series of tabular statements giving summaries of all the principal tables hitherto published for the species discussed. Chapter VI deals with the rate of growth in relation to factors of locality. There is a bibliography of thirty-seven references, and seven plates showing the more notable stands of conifers in Great Britain. In an Appendix the data are given for each of the 1,166 plots used to construct the yield tables.

Nursery Investigations. H. M. Steven. *Forestry Commission Bulletin*, No. 11 1928. H.M. Stationery Office. Price 3*s.* 6*d.*

THIS bulletin presents the results of investigations into methods of raising conifers, carried out by the Forestry Commission research officers during the period 1920–8.

Chapter I discusses the importance of nursery practice in Great Britain, while Chapter II gives an outline of existing methods. Chapter III deals with the methods of investigation. The principal departure from those used in the past for such investigations is the introduction of methods of plot replication such as are now used in similar agricultural experiments. Uniformity trials carried out by different investigators for agricultural plants showed that great differences in yield may be obtained as the result of soil heterogeneity, hence if there is only one plot for each treatment, notable differences in yield may be given which are not due to the treatments, but to soil heterogeneity, leading to erroneous conclusions. Data are given in this bulletin which show that this applies to tree crops also. Methods of plot replication which meet this difficulty, such as the Latin Square Chessboard and Randomized Blocks, were used, and methods of statistical analysis after Fisher and others, appropriate to these methods of lay-out, were applied.

Chapters IV to XVII present the data for 118 experiments. These deal with the following subjects: Season of sowing, treatment of seed, method and density of sowing, size of seed, depth of sowing, tilth, weed problems, summer shelter, winter protection, manuring of seed-beds, season of transplanting, grading of seedlings, spacing of transplants and other transplant investigations. There is a bibliography of fifty-eight titles, and six plates illustrating plants from different treatments. There are four appendices including a description of the methods of statistical analysis employed.

Lyctus Powder-post Beetles. R. C. Fisher, B.Sc., Ph.D., Department of Scient. and Indust. Research. *Forest Products Research Bulletin*, No. 2, 1928. H.M. Stationery Office. Price 3*s*.

THIS bulletin presents the result of research carried out during the past two and a half years, certain aspects of which were dealt with by Dr. Fisher in *Forestry*, ii, pp. 40–6. Part I is introductory, while Part II gives the life-history and habits of the *Lyctus* beetles. Of the four species present in Great Britain, only *L. linearis* is indigenous, although *L. brunneus*, an American species, is now the most numerous. Part III deals with the timbers attacked. Only species of timber with pores or wood vessels such as oak, ash, sweet chestnut, are liable to be infected, because the eggs are laid in the pores. Attack is confined to the sapwood. Part IV discusses the economic importance of powder-post beetles. It is only since the War that the *Lyctus* problem has assumed large proportions, and it has been established that these beetles are coming into the country in certain grades of American ash and oak. Part V deals with control and remedial measures. Biological control of *Lyctus* beetles by their natural enemies is unlikely to be effective. The principal methods of control are removal of the sap-wood, attention to general hygiene in the timber yards, and sterilization by moist heat. The latter is effective, but does not render the timber immune to re-infestation.

There is a note on 'Heat Sterilization of Timber in Relation to Kiln Seasoning' by S. T. C. Stillwell, B.Sc., and another on 'Vessel Size and the Liability of Woods to *Lyctus* Attack', by S. H. Clarke, B.Sc., which is a summary of a contribution to *Forestry*, ii, pp. 47–52. There is a bibliography of 37 titles, 10 plates, and 4 appendices.

SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed in 1925 and adopted its first Constitution at Oxford in 1926. Since publication of the last number of this Journal, that constitution has been amended in certain respects. The object remains as before, viz. to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

Professional membership has now been divided into two Orders:
FELLOWS, being holders of a degree or diploma in forestry, and subjects of the British Crown, but not necessarily resident in Great Britain; and
ASSOCIATES, being subjects of the British Crown resident in Great Britain, whole-time foresters and not eligible for Fellowship. They pay a less subscription than Fellows but have almost equal privileges.

Ordinary membership is open to persons not eligible for either of the above.

Office-bearers and Councillors are nominated by Professional Members, and in the event of competition for any office a postal ballot of the whole Professional Membership is held. The following were elected to serve in 1929:

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THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this society should be represen-

tative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as ordinary members.

THE SOCIETY'S JOURNAL, called *Forestry*, was published as a single annual volume in 1927 and 1928, but this year the volume is being published in two parts. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others, resident either in Great Britain or abroad. They should be sent to the editor, Dr. H. M. Steven, Imperial Forestry Institute, Oxford. The papers should be typewritten, and on one side of the paper only. The paper should conclude with a summary of contents. It is understood that an article is not offered to any other journal for prior or simultaneous publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number, enclosed in brackets. Twenty reprints of the article will be sent free to each contributor. Additional reprints may be purchased if ordered at the time when proofs are returned.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, R. Angus Galloway, 8 Rutland Square, Edinburgh.

MEDALS

1. THE MEDAL offered by the President of 1928, not having been won during that year, is again offered on the same terms, namely: to the member who shall make the most outstanding contribution to forestry knowledge in any of its branches in the course of the current year.

2. A MEDAL is offered by the President of this year for 'An essay upon the creation and treatment of plantations with a view to obtaining revenue from thinnings at an early date without detriment to the permanent crop'.

IN BOTH CASES the contributions must be lodged with the Secretary not later that the 31st December 1929.

COMPETITORS should write under a *nom de plume*, and a sealed envelope bearing the *nom de plume* outside, and containing the competitor's name and address, should accompany the contribution. The envelopes will be opened at the meeting at which the adjudicator's awards are announced.

THE INTENTION of the Council is to publish the successful contribution in *Forestry*, in each case; and while it is desired to have the privilege of selecting any of the other contributions for publication, there can be no undertaking to publish them.

FORESTRY

CONTENTS OF VOLUME III, NUMBER 2

Address to Society. By the PRESIDENT 81

The Second Annual Excursion of the Society 85

Environment and Disease, a Discussion on the Parasitism of *Armillaria mellea* Vahl. Fr. By W. R. DAY 94

Silvicultural Research in India, its Organization, Problems, and Methods. By H. G. CHAMPION 104

Forest Soil Science in Sweden. By G. V. JACKS 118

Afforestation in South Africa. By H. M. STEVEN 124

A Report on the Proceedings of the Seventh International Congress of Forest Research Stations, held in Stockholm, July 1929. By W. H. GUILLEBAUD 134

The Forestry Sub-Section of the British Association Meeting, South Africa, 1929 142

REVIEWS:

The Structure and Life of Forest Trees (BÜSGEN, MÜNCH, THOMSON). By R. N. ALDRICH-BLAKE 144

The Role of Research in the Development of Forestry in North America (I. W. BAILEY and H. A. SPOEHR). By the EDITOR 145

British Hardwoods (L. CHALK and B. J. RENDLE). By S. H. CLARKE . 146

Forestry (A. B. RECHNAGEL and S. N. SPRING). By W. L. TAYLOR . . 147

Le pin Weymouth en Suisse (H. BADOUX), and Holz, Blattmenge und Zuwachs. I. Die Weymouthsföhre (HANS BURGER). By the EDITOR . 147

Untersuchungen über die Weisstannenlaus *Dreyfusia nüsslini* C. B. in der Schweiz (O. SCHNEIDER-ORELLI, C. SCHAEFFER, and R. WIESMANN). By R. N. CHRYSTAL 148

Plant Ecology (J. E. WEAVER and F. E. CLEMENTS). By the EDITOR . . 149

NOTICES:

Report of the Forest Products Research Board for the Period ending 30th September 1928 151

The Practice of Silviculture (R. C. HAWLEY) 151

Le Sol et la Forêt (E. HESS) 151

Notes on some Forest (Site) Types in North America (YRJÖ ILVESSALO) . 154

A Tree Classification and Thinning System (LAURI ILVESSALO) . . 154

ADDRESS[1] TO THE SOCIETY OF FORESTERS OF GREAT BRITAIN

J. D. SUTHERLAND, C.B.E., LL.D., PRESIDENT OF THE SOCIETY

IN the first place, I would refer to the position of the Society. The institution of it was described as a hazardous venture, but the success which has followed in the last two years has proved that it was required to strengthen the position of technical foresters and to aid them in conveying the results of special and original studies to not only their fellow members but to a much wider circle interested in the science and practice of silviculture. The membership does not increase by striking leaps, still we are quietly but surely adding to the roll. We have now well passed the hundred datum line which was our original ambition.

Although our coffers do not overflow, the financial position is absolutely sound, and I would invite you individually during this year to urge at least one professional friend to join our ranks. You can easily convince them of the advantage to themselves as well as to the general welfare of the objects we have in view.

The three numbers of *Forestry* already published, have been favourably reviewed by newspapers and by scientific and other periodicals at home and abroad, and one of the most promising features is the foreign and colonial demand for it. Already the list of these subscribers numbers two or three score, besides which our publishers have reported satisfactory sales to the public. You will agree that the hitherto excellent standard of the Journal must be rigidly maintained. It is proposed to distribute two numbers during the current year. For our past success we are indebted to Dr. H. M. Steven, to the Editing Committee, and to those who have contributed the articles and reviews.

Your Society with youthful audacity initiated the conference which is shortly to take place between the Forestry Associations in Britain, and it is hoped that by mutual consideration and combined effort the usefulness of all of them may be multiplied. So many changes have occurred since the opening of this century that, while remembering the past, we must set our aspirations and energies upon the future. There is much to achieve.

Surveying the past we find that silviculture, the cuckoo of agriculture, might only lay its plantations unobtrusively in secluded spots where and when agriculture could not swoop down in protest. It received no encouragement from the State and was supported only by the members of the older forestry institutions, to whom all honour is due. Education in forestry was then almost a luxury, opening no promising opportunity for the graduate except India. Research was disconnected and intermittent, duplicated often for lack of intercourse between the workers, and too often passed without recognition or publication.

[1] Given at a meeting held in Oxford on the 17th May 1929.

The Forestry Act and its legislative supplements have altered the whole situation, and now afforestation by the State proceeds apace. Following upon a sensible appreciation of forest importance in national economics there has been in the last fifteen years a world-wide movement towards the creation and preservation of forests. As a result, educational facilities have increased, and the field for trained foresters has enlarged at home and in practically every unit of the Empire.

Of all the participants in this awakening industry qualified men are the most important. The question arises whether they are being provided with the best opportunities of acquiring the knowledge requisite to a forest career.[1] It seems to me the effort is to try to equip them in the class-room without any very direct instruction in, at all events, certain of the attributes which they are expected to possess when they pass to the forest. For example, it is found that graduates emerge from universities without sufficient knowledge of the life and history of even common plants—most of them indicators of soil suitability, or in other words of planting possibilities. Is it not possible to provide some more regular and useful acquaintance with the home forest during the curriculum? A short sojourn in Continental forests, while helpful, seems very inadequate for the object in view. Agriculture, in my opinion, brings the student closer to the soil and the capabilities and cultivation of it than silviculture has so far accomplished. It might be well to study the agricultural teaching systems.

The schools for forester trainees who are brought up under working conditions produce men who have gained experience in the woods, and they are even better qualified in some spheres of forestry than men who come fresh from a university. A consultation between teachers and those who departmentally and privately employ technical men might bring about a fuller understanding of the directions in which improvement is desirable. It would almost appear that there are now too many higher forestry schools in this country, and an investigation into the facilities and training at each of them might tend to decrease unnecessary expenditure and at the same time increase efficiency. We must not forget that the technical forester as a rule enters the forest and embarks upon practical supervision of plantations and woodlands at the very commencement of his career.

Research is closely associated with education, and there is of course a clear line of division between pure science and what may be termed the search for information through experiment. We all recognize the supreme importance of the former, but a large range of studies by simple experiment can be of very great value. In other words specialization in forestry need not always be highly scientific.[2]

[1] Subsequent to this address the Society of American Foresters has undertaken an investigation of the problems of forest education for which the Carnegie Corporation of New York has given a grant of $30,000.

[2] See Bailey and Spoehr, 'The Role of Research in the Development of Forestry in North America', review p. 145 of this number.

At present research is progressing in many directions and it may be classified into four divisions:

1. Departmental.
2. University or College.
3. Independent, as upon private property.
4. Individual.

Departmental research of itself cannot be enough, but it has the choice of selected objectives which can, with advantage, be linked up with university or college organizations. A Department may properly carry out many investigations independently, but this policy is often of necessity screened from public view until absolute confidence in the result is assured. We have in the study of the utilization of forest products a great departmental example at Princes Risborough. There research is carried out with an intensity that forms an object lesson. The investigations proceed on selected subjects without check by a wonderful team in which science and practice are combined in harmony, but even at Princes Risborough the Director will acknowledge that co-operation with agencies outside the Laboratory are of material consequence and, in many studies, essential to success.

University projects in research frequently never reach the light, and the same may be said of private experiments. There seems in fact to be room for a closer point of contact between all investigators. I think contact of the kind can be brought about through the medium of this Society.

Particularly should individual research be encouraged and some guidance given to those who are prepared to take up definite subjects. The Editor of our Journal might invite suggestions on the subject and give an assurance that the results of all creditable work, whether negative or otherwise, will be published by the Society. Various problems in the direction of research have to be faced in this country, and some call for rather urgent attention. There is a large and accumulating responsibility in young woods. Have we prepared or are we preparing for an assault upon agencies of destruction which may without much warning descend upon us? Do we know enough about, or have we devised methods to defeat, the invasions of insects and fungi to which the predominating species of trees growing in Britain are liable? I emphasize the predominant species because they must be the first consideration. The protection of trees of minor importance can follow. Do we know the sources from which all of the attacking forces may spring, and are we on the alert to circumvent their descent upon us? We cannot be content to rest upon the research of the past. The risk can be well exemplified by one occurrence in the United States. The ravages of the Chestnut blight (*Endothia parasitica*) a fungus disease native to China and Japan. It was first identified in the Bronx Park, New York, in 1904, and it spread southwards at the rate of 240 miles in ten years until now the American Chestnut (*Castanea dentata*) has almost been exterminated.

Another matter for special investigation at the moment is the danger of fire. It may seem a simple subject, devoid of scientific import, but it is real and

deserving of attention. Our fire problem is rather different from that in other countries, and the application of methods adopted by them does not appear to be enough.

Other subjects might be submitted in this direction such as the classification of sites, but I would close by again placing stress upon the importance of encouraging individual investigations both in science and experiment. Some lead or direction is obviously necessary. Volunteers I am convinced could be readily enlisted, and the Society of Foresters through the Council might well recommend some themes.

Away from research there are many directions in which information could be collected by reliable observers. If only a chain of observation could be linked up all over the kingdom to provide reports upon natural phenomena such as the, with us, very uncertain weather, this information, if compiled and garnished with the effect upon the life of the tree would add material of interest and guidance to all of us.

THE SOCIETY'S SECOND ANNUAL EXCURSION

BENMORE, ARGYLLSHIRE—23rd to 27th SEPTEMBER 1929

BY the President's kind invitation, the Society were privileged to be the first to enjoy the hospitality of the Forestry Commission's Hostel in Benmore House, the gift of Mr. Harry G. Younger to the nation for forestry education. Twenty members attended, of whom fourteen were accommodated in the hostel. Mr. Younger, who was living in the vicinity, joined the outings on most days and contributed much valuable information on the past history of the woods.

Benmore is an excellent centre for forestry study. It lies in a district where rainfall is comparatively heavy, and the specimen trees in the pinetum demonstrate how exotic trees from regions with different rainfalls are adapting themselves more or less-successfully to local conditions. On the surrounding hill-sides, which are generally very steep, the soil conditions vary almost from yard to yard, the soil being good, but in many places very thin and often very wet. Many interesting problems in the selection of species thus present themselves, and a special system of classification of soil-types has been evolved to deal with these in practice. There are also plantations now about sixty years old which afford lessons on the wisdom or otherwise of the selections made by their planters. A number of sample plots had been prepared by the Commission's officers and school trainers: a study of these occupied the whole of the first day. The results of the visits to these may be summarized as under:

The morning was devoted to an inspection of Cruach wood aged 50 years, and the afternoon to Uig wood aged approximately 58 years. In the evening a general discussion took place on the very interesting problems which these two woods present.

Both woods lie on mica schist, the slopes are steep, Cruach wood facing east and Uig west, and the rock forms numerous small precipitous faces immediately above which the soil is very shallow and peaty. In the hollows the soil is wet and inclined to be peaty, while between there are stretches of firm ground with a deep yellow loam. There is generally in these situations a top layer of three or four inches of peaty humus, next a couple of inches of leached soil, and below the yellow loam.

Cruach wood was planted extensively with Western American Conifers, including Douglas fir, *Abies nobilis*, *Thuja plicata*, and some Sitka spruce at the higher elevations, as well as with Scots pine, Norway spruce, and larch. Uig wood consists chiefly of larch, Scots pine and spruce, with some Douglas fir.

In both woods a series of plots had been laid out and measured, so that it was possible in Cruach wood to trace the effect of elevation on most of the species mentioned, and in Uig the effect of elevation on larch, Scots pine, and Norway spruce.

THE CRUACH PLOTS.

The following table illustrates for Cruach wood the dimensions attained by different species at different elevations, the age in all cases being 50 years.

Plot No.	*Elevation. ft.*	*Species.*	*Height.*	*Girth breast height. in.*	*Average volume per tree. cu. ft. Q.G.*
I	144	Douglas fir	102	54	42·4
		A. nobilis	99	47	51
		Norway spruce			
		Scots pine			
		European larch	81	32·5	9·45
II	194	Douglas fir	108	49·5	39·9
		A. nobilis	97·5	32·5	29·6
		Norway spruce			
		Scots pine			
		European larch			
V	344	Douglas fir	96	44·5	32·6
		Norway spruce	79·5	33·5	17
		European larch	48	27	5·7
VI	429	Douglas fir	84	42·5	17·5
		Norway spruce	62	27·5	10·1
		European larch	64	25	9·4
VII	594	Douglas fir	69	34·5	18·5
		Norway spruce	43	22	4·8
		European larch	52	21·5	7·5
		Scots pine			
X	743	Douglas fir	60	30·5	10·2
		Norway spruce	53	22	6·2
		European larch	62	19·5	6·2
		Scots pine			
XI	834	Douglas fir	52	23	6·9
		Norway spruce	47	21	4·6
		European larch	40	19	3·3
		Scots pine			
XII		Sitka spruce	73	29	11·3
		Norway spruce	46	23·75	6·9

An additional plot visited was one established by Dr. Nisbet in 1911 when it contained 3,420 cubic feet of Douglas. The present volume is 8,780 cubic feet, the periodic increment has consequently been 5·1 per cent. Borings taken from average trees showed that wood is now being laid on at the rate of 10 rings per inch. Work at the Forest Products Research Laboratory shows that an average ring width of 8 per inch is sufficient for most purposes, and the conclusion on these grounds (which agreed with the silvicultural state of the crop) was that thinnings might now be begun on a heavier scale.

The plots indicate how quickly the height-growth of Douglas fir falls off in Cruach wood with increasing elevation: at 500 feet it was only about 65 per cent. of that at 150 feet, and at 830 feet only 50 per cent. These plots have

developed for the most part out of mixed plantations and the rate of growth of individual species in the early stages has had much to do with their chances of growth in the later stages. Thus the slow starting spruce has been killed out where Douglas fir has started quickly, but begins to assert itself as the slope is ascended until it grows nearly as quickly as Douglas (47 feet against 52 feet) at 834 feet elevation. Scots pine although a quick starter does not appear to be at home, and has disappeared or become badly suppressed except in pure stands. European larch has behaved better, but finds great difficulty in finding sufficient crown space in mixture with Douglas at the middle elevations (it is suppressed at the lower) or in competition with Norway spruce at the higher elevations. The most remarkable feature at the high elevations is the excellent growth of Sitka spruce, which is more than half as high again as Norway spruce (73 feet against 46 feet) and provides per acre as much timber as does Douglas at the lowest elevation.

THE UIG PLOTS.

In elevation these plots ranged from about 100 feet up to 700 feet. The three species, Scots pine, European larch, and Norway spruce, occurred under various combinations of soils and elevations, and it was not possible to trace clearly the effect of elevation. In general Scots pine has done poorly. At 58 years its height varied from 34 to 54 feet, while the stems were rough and the tops frequently badly formed. Larch on the firm ground was as tall as 79½ feet, and Norway spruce in the wet hollows (where it was chiefly planted) reached 59 feet and averaged about 55 feet. The fall off in growth of both larch and spruce was not very marked at 700 feet. Scattered Douglas fir throughout the crop overtopped the other species by many feet.

A Japanese larch wood at about 100 feet elevation provided some useful figures. Planted 22 years ago at a cost of £9 per acre it now contains 2,150 cubic feet per acre and is worth over £50 per acre. Thinnings to the value of £61 per acre have been removed in the last 3 years. If 5 per cent. interest is allowed on all outgoings, viz.—formation charges, overhead charges, rent and rates; those thinnings give a credit margin of over £20 per acre.

Mr. C. J. Chaplin, in charge of Timber Mechanics at the Forest Products Research Laboratory, and Mr. B. J. Rendle, Officer in charge of Wood Technology at the same Laboratory, were present and gave their experiences of Douglas fir timber from Benmore supplied to them for investigation. The following is a summary of their remarks.

A note on some structural and mechanical characteristics of Benmore Douglas fir.

The effect of the spacing of Douglas fir in plantations upon the rate of growth of the timber was studied at the Forest Products Research Laboratory with reference to disks cut from twelve trees, six of which had been close grown and six open grown. Three disks had been cut from each of the twelve trees at heights of 0 feet (Disk A), 9 feet (Disk B), and 18 feet (Disk C) above stump level. The rate of growth as shown in each disk was measured along two radii,

and the number of rings included in each inch was noted. The average of the measurements along the two radii was then tabulated.

Difference in character of the timber as shown in the cross-sections was very marked, and Mr. B. J. Rendle has summarized his observations as follows:

'The close grown Douglas fir starts off at 4½ rings per inch, the rate falling to 6 rings per inch after about the 10th year. Between the 20th and 30th years the average rate is about 12–15 rings per inch, but before the 30th year is reached the rate falls rapidly to 20 or more rings per inch.

'The open grown starts off at about 3 rings per inch—rarely slows down to 5 rings per inch before the 25th year. In the more vigorous trees there is little sign of rate of growth falling off even at 42 years of age. In others the rate begins to fall off slightly in the upper part of the tree but not at the base.'

A comparison of two trees of the same age, one from each of the two groups, is interesting, and it will be seen from the table, that the yearly increment in tree W 2, open grown, remains almost constant to the 30th year and then decreases only slightly, whereas tree C 4, close grown, shows a falling off in increment after the 8th or 9th year, while after 16 years it is increasing in diameter comparatively slowly.

	Tree W 2, Age 42 yrs.			*Tree C 4, Age 42 yrs.*		
	A	B	C	A	B	C
1st inch . . .	4½	3½	3	4½	5	4½
2nd „ . . .	3	3	3	3½	4	4½
3rd „ . . .	4	3	3	5	7	6
4th „ . . .	4	3½	3	10	18	15
5th „ . . .	3½	4	4½	'19'	—	—
6th „ . . .	4	5	5½			
7th „ . . .	5	6	6			
8th „ . . .	6	7	8			
9th „ . . .	6	—	—			

Specimens for specific gravity determinations were then cut from the disks and the results of these tests were plotted with relation to their rate of growth as expressed in rings per inch. A mean curve was drawn through each of the two series of points and the two curves are shown in Fig. 1 as 'Benmore open grown' and 'Benmore close grown'. A third curve representing the same characteristics as found in the large consignment of Douglas fir from Argyllshire tested at the Laboratory last year is drawn on the same base for the sake of comparison. The curves have a similar general character, and it will be noted that the open grown timber acquires a greater density than does the close grown at the same rate of growth.

A curve of specific gravity plotted on rings per inch for the Argyll consignment is represented in Fig. 2, and with this is plotted a curve of maximum compressive stress. It will be seen that the strength of the timber in compression increases as the rate of growth diminishes, and this trend is generally followed by the other mechanical properties. This increase for the Taymount

Douglas fir as shown by a similar curve reached a maximum of about 8 or 9 rings to the inch, after which the strength fell off with further retarding of the rate of growth.

Timber with mechanical properties which would render it suitable for

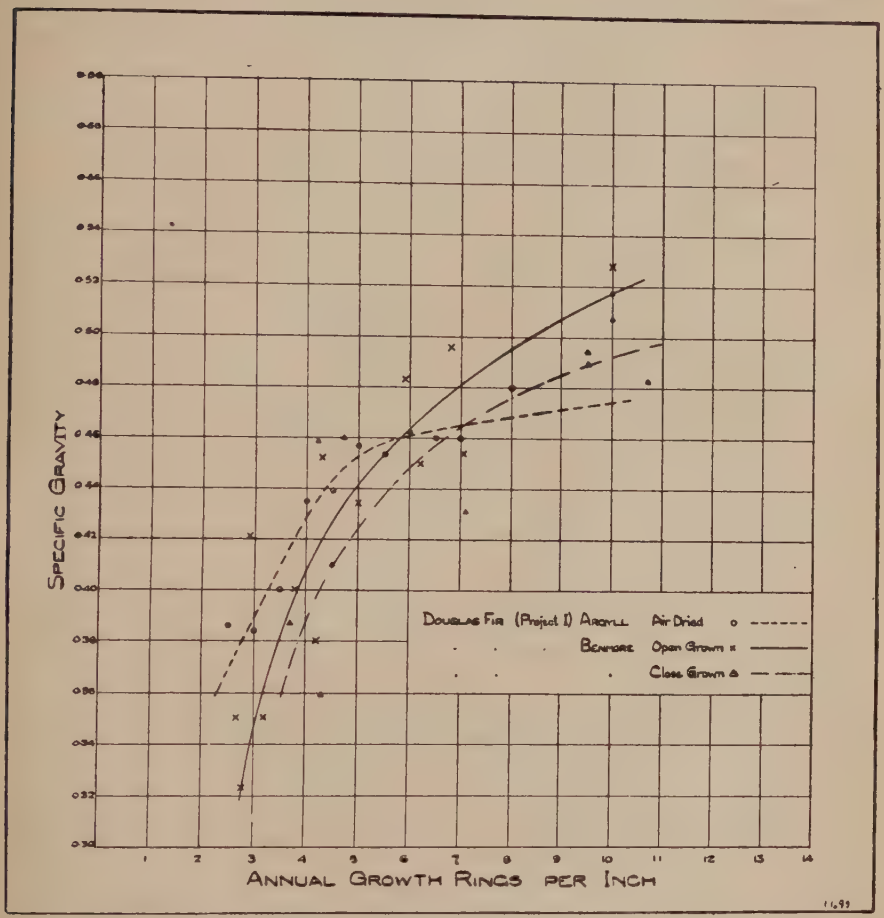
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Fig. 1. The effect of rate of growth upon the density of Douglas fir when close grown or open grown.

structural purposes is found in the Taymount consignment grown at rates ranging from 6 rings per inch to 14 rings per inch.

The material from Argyllshire yielded few specimens with slower growth than 7 or 8 rings, and the optimum rate could not be defined.

That density is a good indication of strength value is shown in Fig. 3, where maximum compressive stress is plotted on specific gravity. This curve is characteristic of this mechanical property in timber generally.

Other tests on both the consignments of Douglas fir showed that the timber grown slower than 6 rings to the inch is more generally useful, not only in

structural work but in joinery and woodworking, than is the faster grown timber.

Classification of soil types by means of vegetation types.

On the second day particular attention was directed to this subject, under the guidance of Mr. J. M. Murray, divisional officer, and Mr. James Fraser, district officer, and a summary of their views is now given.

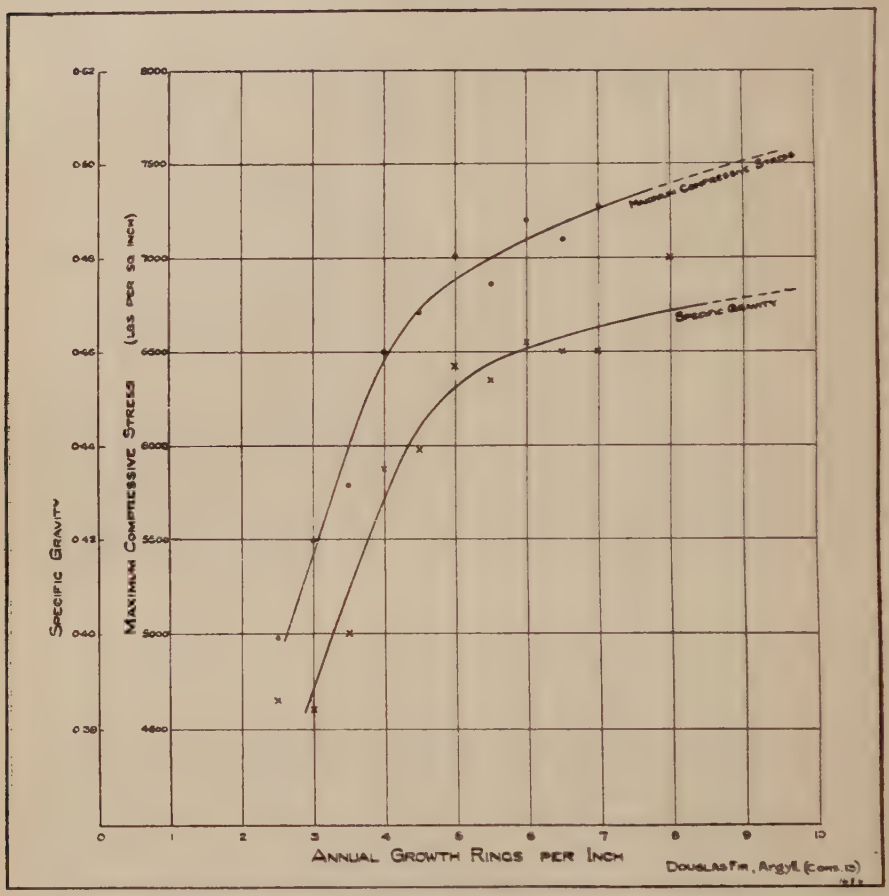

Fig. 2. Showing the similar trend followed by specific gravity and strength in compression parallel to grain when based on rate of growth.

The classification of soil types for forestry purposes has as its ultimate goal the provision of a method of assessment of the timber producing value of the soil. We are far from that goal, and we have not yet decided on the route which we should take to reach it. There is work for an ecologist who can appreciate the difficulties which a forester has in the description of his plantable land, and in framing his programme for planting land that has not carried a tree growth.

At meetings of foresters within the last few years, there have been many

discussions which showed, while there are different views on the way in which soil classification may be made, that there is perfect agreement as to the necessity for a convenient workable system of soil description, and that it might be based on the characters of the surface vegetation.

The vegetation types that were suggested to the members of the Society

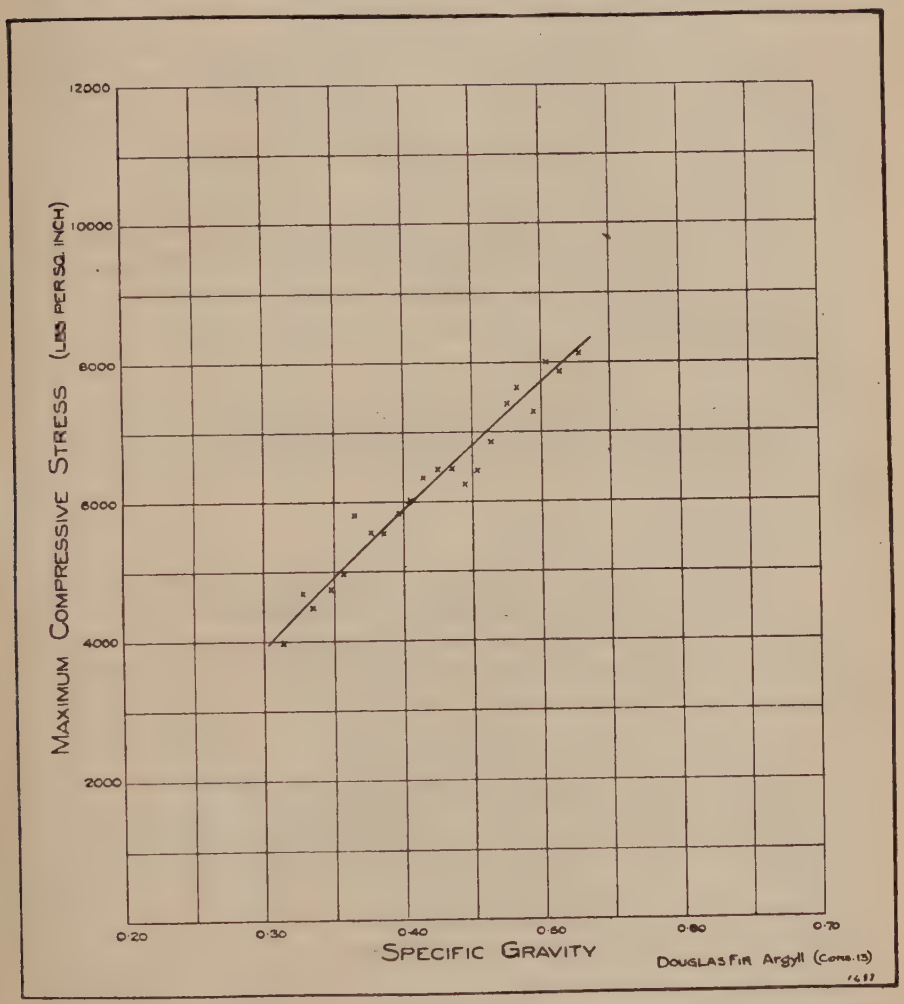

Fig. 3. Showing the relation between strength in compression parallel to grain and specific gravity.

on the occasion of the visit to Argyll are not strictly the 'types' of an ecologist. The types are 'descriptive types': the associations given occur commonly and on that account it may be convenient and helpful to describe land in terms of those types. Their boundaries have been modified by views expressed by men who work in conditions similar to those found in Argyll, and there must be the defects which accompany boundary adjustment. It appears, however, that

the types are sufficiently clear to be used as convenient descriptive terms. There is room for investigation as to the permanency of the types, their boundaries, the relative value of the soil which carry the types, the nature of the soil conditions indicated by the types, and the value of them as a guide to the species which should be used in planting. Discussion on those lines would be of interest.

The route taken by the Society on Tuesday was planned to show the types which might be adopted and also to show the changes that take place in surface vegetation as a result of enclosure. The land examined lies on the hill faces on each side of Lock Eck. The types recognized are:

1. *Grass-fern-herb—rich type.*

This type can be subdivided into several subsections. It includes the best quality of scrub ground in the district: and also moist types in which luxuriant *Molinia* is plentiful, and in this moist sub-type the closest approach is made to the rich *Juncus* type.

2. *Grass-fern type.*

This type might possibly be placed as a drier grade of type 1, but it is not rich in herbs. It has as its most common grass, *Agrostis spp.* or big tufts of luxuriant *Aira flexuosa.*

3. *Nardus-Agrostis-Calluna type.*

This type must be wide enough to include moraine mounds and ridges and burnside ridges, small dry areas on landslides, and shallow wash deposits over rock shelves. This type, if extended widely enough, would include east coast areas in which *Calluna* and *Vaccinium* are dominant plants, and in which *Calluna* may be the most prominent plant.

4. *Vaccinium-Juncus squarrosus-Aira flexuosa type.*

This is commonly the upper limit type in the west. It is not to be confused with the type in which *Vaccinium* and *Calluna* are the dominant plants. It graduates into 3 in one direction and into 6 and 8 in the other.

5. *Scirpus-Molinia-Juncus squarrosus type.*

This is a peat type of big rock hummocks and rock flats, and it may be a phase of 6, due to heavy sheep grazing.

6. *Scirpus-Calluna-Molinia type.*

7. *Juncus-Grass-Herb type.*

8. *Juncus: poor type.*

The poor types of *Juncus* land shade into 5 and 6.

The programme for the third day included a visit to Sligrachan Wood, the plantation of 1927/28 at Glenfinart, and the plantations and old woods on

Kilmun Hill. A short visit to Glenfinart Nursery was also included in the programme.

A visit was made to Puck's Glen on the outward journey.

The route for the day was planned to show the limitations of the methods of soil valuation by means of vegetation types alone. There were also included in the route planned out, good examples of the types already described. In Sligrachan Wood European larches of excellent quality and dimensions were to be seen growing in hard drift covered by a vegetation that would probably have led a forester to select Sitka spruce and pines planted in small groups. In Kilmun young plantation, a good demonstration was available of the quick changes that occur in the surface conditions within very small areas. In Kilmun old plantations there could be seen a very excellent example of the sharp influence of elevation, and on the upper limit of the standing wood there was a clear demonstration of how values based on surface vegetation types must be used along with other locality factors; a valuation based on surface vegetation types alone is just as dangerous as any other one-sided method of valuation. An interesting discussion arose as to the comparative worth of Sitka spruce and Norway spruce as high elevation species.

A plantation of *Tsuga heterophylla* of the same age as the larches, spruces, and pines, in the old plantation was also seen in the descent from the old woods on Kilmun Hill.

The excursion concluded with a short visit to the yacht-building yard of Messrs. A. Robertson & Sons, Ltd., at Sandbank. Although of great interest as a demonstration of fine craftsmanship, the visit was appreciated mainly for the opportunity it afforded of seeing the species and grades of timber used in boat-building. A number of small boats were under construction, and it was found that the hardwoods employed for the framework consisted either of oak or elm grown at home or of such foreign woods as teak. For the boatskins native larch is probably the most popular, but Sitka spruce and Yellow pine are also in use, in all cases very straight in the grain and free from knots.

On one evening an informal dinner was held in the Hostel at which Mr. Younger was present as guest of the Society, and received from the President's hands an interesting volume suitably inscribed as a souvenir of the opening of the Benmore Hostel as a residence for forestry students.

ENVIRONMENT AND DISEASE

A Discussion on the Parasitism of *Armillaria mellea* Vahl. Fr.

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PREDISPOSING FACTORS AND TYPES OF ENVIRONMENT.

THE environment of a forest tree presents an extremely complex problem for examination, and it is only rarely that in the study of disease the environmental factors acting as its primary causes are so obvious as to be capable of immediate discovery. An attempt will be made to define what a primary cause of disease is, and to give the distinction between this and a factor predisposing to disease. A primary cause of disease is any factor in the environment, which in the development of a diseased state, is the first to bring about a morbid condition. A factor predisposing to disease, however, in no way tends in itself to bring about such a condition: it merely makes it possible for a primary cause to do so. Thus in Britain early flushing in exotic conifers is a factor predisposing to damage by late frost, the primary cause of disease. Again, cloudy weather may be a factor predisposing pines to infection by *Cronartium ribicola* (20) in that it provides the conditions necessary for the successful production and distribution of the infecting basidiospores. Such examples might be multiplied indefinitely, and it is obvious that, if disease is to be controlled, both the predisposing factors and its primary causes must be understood. A second distinction is also necessary. It must be possible to distinguish between the factors acting as primary causes and those acting subsequently and in a secondary manner. Thus the crown of a tree severely affected by drought may be rapidly killed back by a bark-infesting fungus, which would be unable to attack a tree in full vigour. The factors concerned with disease may thus, by the adding of one factor to another, become numerous, and it is not always the most obvious that are the most important.

In considering environment in relation to disease it will also be of service to state what types of environment occur. First, there are two main types, the biological and the physical, and disease may arise owing to adverse factors in either of these or in both acting together. The physical environment is again of two kinds, edaphic and climatic; and again disease may be due to adverse edaphic or climatic factors acting separately or together with or without the interference of biological factors. Apart from all this there are the inherent characteristics of the forest tree to be taken into account. Disease is always produced by the interaction between the host and one or more of the types of environmental factor enumerated above, and it is to be prevented by removing or avoiding the adverse factors, or by producing a race of tree capable of withstanding them without injury.

THE PARASITE AND ENVIRONMENT.

The plant parasites causing forest diseases may be divided into classes according to the extent to which they depend on the pre-existence of a morbid condition in the host in order to be able to live upon it. Certain fungi appear able to parasitize a perfectly healthy tree; the rusts and mildews provide examples of this. A certain state in the host or condition in the environment may be necessary to successful infection, but such state or condition does not involve the host being diseased: it is merely susceptible and nothing more. It is probably true, however, that the majority of cryptogamic parasites are more easily able to attack and to develop within a host that is in a morbid condition than in one that is perfectly healthy, and it is certain that some parasites have very little power to do damage unless such a condition exists. Now, although we are not much accustomed so to think of it in Forestry, such a morbid condition, however slight it may be, is essentially a state of disease. The factors that bring it about are the primary causes of disease, and their relation to the host needs to be understood if the prevention of disease is to be really efficient.

It is customary to speak loosely regarding diseases with which parasites are associated, assuming that the parasite is the sole factor with which one need be concerned, whereas other factors may be more necessary to the production of the diseased condition. One evil result of this is that fundamental causes tend to be overlooked and attention concentrated on the obvious factors in the problem, even though these may be of secondary importance. The root rots of forest trees provide good examples of this. In Europe, where conifers are of predominating economic importance, two fungi, *Armillaria mellea* (Vahl.) Fr. and *Fomes annosus* Fr. are pre-eminent as causes of this type of disease. *F. annosus* is acknowledged to be a doubtful parasite (12). The parasitism of *A. mellea* is, however, well established, and all that may be in question is the degree to which it is a parasite. What are the factors in the environment of the tree that predispose it to infection? Are these such as merely enable the fungus to penetrate the host, without in themselves producing in it a morbid condition, or is it necessary for such a condition to exist before the host is unable to resist infection? These are important questions for if it is true that the fungus depends for successful parasitism upon a pre-existing morbid condition in the host, it should be known what such a condition is and how it is brought about. For the means by which this condition is produced is the real cause of disease and should be referred to as such. The importance of speaking thus strictly with regard to disease is that only by so doing is the fundamental cause brought to light and the silviculturist enabled to turn his attention to its removal. If an examination is made of what is known about *A. mellea*, what conclusions must be come to with regard to its status as a parasite?

THE HABITAT OF THE FUNGUS.

A. mellea is strictly a forest fungus and occurs in cultivated land only after it has recently been cleared of woodland or when it borders the forest. Its world-wide distribution, its many hosts, and the loss that it continually causes wherever it is found make it one of the most interesting and widely noticed

of fungi. In one or other connexion it has been described on a number of occasions (11, 12, 14, 5, 3 and 6 *a*). Its general characteristics and those of the disease it causes as a parasite are too well known to need any description, and for the purpose of this discussion I wish to stress only one or two things concerning it. The fungus is subterranean, growing on dead roots and stumps as a saprophyte, sometimes attacking living trees and then growing above the soil, but only beneath the bark of its victims. Once this has dried out it ceases to grow and other fungi may replace it. Its rhizomorphs and the sheets and zones of xylostroma formed in the bark and wood of its hosts are the typical features of its mycelium. Like all fungi a humid atmosphere is a necessity to its existence, but unlike many others it is able to protect itself against dry conditions. Thus the xylostroma after it has become dark coloured has, as one function, the preservation of a highly humid atmosphere within the substratum within which the fungus is growing. The development of this dark-brown colour depends largely on the humidity of the atmosphere. Thus under very humid conditions in tropical rain forest frills of xylostroma that develop in cracks in the bark of cacao are at first cream in colour (5), and similarly rhizomorphs developing in the extremely humid atmosphere of a humidor grow out of agar cream in colour and turn brown only slowly. Under ordinary conditions, of course, only the tip of the rhizomorph is white or cream, the rest being brown. The conditions prevailing within a mass of substratum surrounded by a zone of xylostroma may be judged by the colour of rhizomorphs within and without it. Within the colour is white or cream, without it is brown, as seen growing in agar. In soil that is always moist and where the temperature is always high rhizomorphs may fail to develop (5). The writer also found in growing the fungus on larch leaf debris and sand mixed that in a dry incubator rhizomorphs developed from the small pieces of branch used as inoculating material, but that none developed in a humidor with a very humid atmosphere, filamentous mycelium only appearing.

A. mellea is thus a fungus demanding extremely humid conditions for growth, but which is able to develop under adverse circumstances by means of the protection against desiccation given by its rhizomorphs and xylostroma. For this reason, while it is associated as a parasite with localities that are definitely moist (5, 18, 15), it is at the same time a common parasite in those which have to endure a dry season during some part of the year, whether as a regular occurrence or brought about by occasional severe droughts (1, 3, 6, 16). No survey ever seems to have been made of its ecological distribution. In natural or semi-natural forest it seems to be confined to broadleaved forest, pure or mixed with conifers. In pure natural conifer forest it seems at least to be rare, but in pure conifer plantations established on the site of old broadleaved forest it is extremely common at least during the first rotation.

THE PARASITISM OF *A. MELLEA*.

As a parasite *A. mellea* appears in two roles. First, it occurs as a purely secondary cause of disease—as, for example, on the oak in Europe (6 *b*), *Picea*

morinda in the Himalaya (13), *P. nigra* and *P. rubra* in N. America (4), *P. excelsa* in Central Europe (16), and *Abies pectinata* in Germany (17). Here the primary cause of disease has been drought, defoliation or mildew (oak), drought and sun-search (*P. morinda*), drought (*P. excelsa*), defoliation and drought (*P. nigra* and *P. rubra*), and an undetermined cause in the case of *A. pectinata*. In its second role, it appears to act as a virulent parasite killing healthy trees, and it is noteworthy that when so acting the fungus is always reported as attacking crops that have been artificially regenerated or grossly interfered with by mankind (3, 5, 6 *a*, 8, 10, 15, 16). It is quite possible that in natural forest the fungus frequently acts in this second role, but if this has been observed it does not appear ever to have been recorded. Is the fungus really a virulent parasite on healthy trees, and why does it so frequently appear to assume this role in artificially established forest and in plantations? There are two lines of inquiry that will help to throw light on these questions. The first seeks to determine what factors are associated with attack by *A. mellea* on apparently healthy trees; the second to establish what is the relative susceptibility of different hosts, and whether the degree of susceptibility ever varies.

THE FUNGUS AS A FACTOR IN THE DISEASE.

It is obvious that unless the fungus is present it cannot attack the tree, but what is much less obvious is whether, if the fungus is present and actively developing, a host, ordinarily stated to be susceptible, will of necessity become infected. It may be noted here that wounds or dead roots are not necessary to enable the fungus to enter a host (6 *a*, 22). Accordingly even if no wounds or dead roots are present a susceptible host is still liable to be infected. Any observations, therefore, will be of value which go to show that in the presence of the actively developing parasite a species may be at one time susceptible and at another resistant.

There is practically no evidence of the fungus growing in direct contact with the living uninjured tissues of possible hosts and yet failing to bring about infection. The writer has, however, observed young developing rhizomorphs growing in the bark at the base of Corsican pine and *Thuja plicata* without the trees in any way being affected. Rhizomorphs have also been observed tightly encircling young Douglas fir without penetrating the trees. All these species are known to be attacked, and, as a matter of fact, were situated in the same wood and on similar soil to specimens of all three species that had definitely been infected. There is much more evidence of conifers having been infected and yet surviving without their growth being in any obvious way checked. Berger (2) observed this on N. spruce in Germany, also Craighead (4) on spruce in Canada, and numerous instances are known to the writer (6 *a*). Cases of this are probably common on broad-leaved species, as on aspen in Sweden (7) and U.S.A. (19), where the fungus causes a butt rot. Geschwind (10) reports this phenomenon also, and the writer has observed it on willow (*Salix alba*), a tree which sometimes succumbs to attack. Altogether there is therefore fairly good evidence that the mere presence of the fungus does not mean that trees will

of necessity be infected and that even when once successfully infected the host may become resistant again. Apart from this there is a great deal of indirect evidence to show that the fungus may be actively growing in the presence of species considered susceptible and yet fail to attack successfully, or only succeed in doing so during a limited period in the life of the crop. Much of this will come forward when discussing susceptibility of species of host.

Taken as a whole the evidence here put forward points to the conclusion that the main factor in deciding whether a host is or is not susceptible is at least not the fungus. For were the fungus capable of killing healthy trees it could hardly fail to cause the death of any that belonged to a species known to be commonly susceptible once it had already infected them. In order to understand the disease it thus becomes necessary to seek the chief causes of susceptibility in factors external both to the host and its parasite. Such factors are chiefly to be sought either in the condition of the soil or in the silvicultural state of the forest. Both of these will now be discussed in relation to susceptibility to infection.

THE CONDITION OF THE SOIL.

As *A. mellea* is a fungus attacking the roots of trees and living in the soil, it is to be expected as probable that any adverse soil condition will heighten the susceptibility of its hosts to infection. When trees that have suffered from drought are infected this is obviously what has happened. Are adverse soil conditions commonly associated with susceptibility to the fungus when attacking apparently healthy trees? Certain cases have been described giving evidence with regard to this. Thus Dade (5) found that the collar crack disease of cacao only became epidemic on level sites with a very high atmospheric humidity and a high soil moisture. On sloping well drained sites death was only sporadic and the losses relatively insignificant. Also Butler (3) found that in tea plantations where the soil was not protected from being washed away by heavy rains and its fertility had become low, *A. mellea* caused serious loss; but where proper care was taken to maintain the fertility of the soil death was only sporadic. Here are two clear cases in which under adverse soil conditions the fungus is a virulent parasite but where under less adverse conditions it becomes very much less virulent. With regard to forest trees no such direct evidence is available. Sometimes, however, these become susceptible under conditions that of necessity involve adverse soil conditions as at least a partial cause. Thus Geschwind (10) observed that in a mixed forest of beech, pine, spruce, and silver fir, *A. mellea* acted as a parasite only after beech had been extracted in preference to other species, with the result that the forest became to consist purely of conifers. The gaps left by the beech failed to fill up with regeneration, became weed covered and gradually the death of the surrounding conifers, owing to infection by *A. mellea* began to take place. The shallow-rooted spruce was affected first, the pine and silver fir being taken later. The change in condition of the forest described here is one that is notoriously accompanied by deterioration in soil fertility and which all foresters in Europe

strenuously try to prevent taking place. This case, therefore, falls into line with the tea and cacao as an attack following or accompanied by deterioration in soil condition.

As in plantations, the moisture content of the forest soil affects susceptibility to infection. Thus Frömbling (8), without giving any details, states that infection by the fungus is associated with very moist soil conditions, agreeing in this with Dade (5), Miège (15), and others. It has been noted already that infection is frequently associated with unduly dry soil conditions, but here it almost certainly occurs after and not during the dry period. Sometimes it may be a definite advantage to have a soil which is always moist, either on account of its power of retention of water or because of the height of the water table. Thus Craighead (4) notes that a correlation seems to exist between abundance of available water and the recovery of spruce and balsam fir from defoliation by the spruce bud-worm. Trees standing in localities in which the soil tended always to be moist recovered to a much greater extent than those on the drier sites. As almost every tree appears to be given its *coup de grâce* by *A. mellea*, it follows that resistance to fungal infection must have depended on the degree of soil moisture. Or perhaps it would be truer to say that upon this depended the ability of the tree to remain sufficiently alive during a period of stress to be resistant to the fungus afterwards.

It is thus seen that where the matter has been investigated or any data given from which the soil conditions may to some extent be deduced, susceptibility or resistance to infection depends largely on the extent to which these favour the development of the tree.

THE SILVICULTURAL STATE OF THE FOREST.

The relationship between the silvicultural state of the forest and infection by *A. mellea* has really never been investigated. That such a relationship does exist can be seen from the case quoted above as described by Geschwind (10). There bad silviculture, or perhaps more truly lack of silviculture, ultimately reduced the forest to such a state that infection became possible. It is probable that the importance of any silvicultural practice lies chiefly in its effect on the soil, and the same practice may not have an equally good effect on all types of soil. It is in this way that apparently contradictory opinions arise. Thus Oppermann (18) writing of spruce (*P. excelsa*), and Wiedemann (21) of conifers in general, recommend that dense stands should be avoided in order to keep down the losses caused by fungi such as *A. mellea* and *F. annosus*; while Frömbling (8) seems to consider the fungus much more innocuous in dense spruce stands than in more open ones. It is apparently also the experience of the latter author that the use of transplants in the artificial regeneration of spruce is accompanied by serious loss owing to *A. mellea*, and he recommends regeneration by sowing *in situ*, for he considers that by this means loss will be avoided. It is, however, by no means a general experience that Norway spruce or any other conifer that is regenerated by the use of transplants always suffers serious loss in this way, and it can only be that special soil conditions account

for the variety of experience. Another phenomenon which points to the association between silvicultural and soil conditions in relation to infection by the fungus is the occurrence at particular stages in the growth of the crop of susceptibility to infection. Thus Hiley (12) notes that larch in England very frequently suffers serious loss at about the age of 15 years. Nechleba (16) finds spruce most susceptible at about 25 years, while Frömbling (8) on the contrary finds it to be most susceptible in the first years after planting and to become less susceptible as the canopy closes. When it is remembered that the fungus is present during the whole time, whether trees are infected with it or not, and that apart from exceptional occurrences, such as drought or defoliation, the chief factor causing alterations in the environment is the crop itself, it can be seen that the manner of regeneration, the degree of thinning and the choice of species may not be without a considerable influence in bringing about susceptibility to infection.

VARIATION IN SUSCEPTIBILITY TO *A. MELLEA*.

It has long been known that different species of host vary in susceptibility to *A. mellea*. Thus broad-leaved trees are generally accepted as being more resistant than conifers. Among the latter many apparent degrees of susceptibility occur, and there are probably many different opinions among foresters as to what those are. Thus in Germany, Hess, as quoted by Nechleba (16), considered Scots pine to be more susceptible than Norway spruce. Nechleba's own experience and also that of Frömbling (8) was exactly the opposite. In Britain it is usual to find Scots pine the more susceptible; indeed, there pines in general seem to be the most susceptible of all species of conifer. Now variations in susceptibility may be, and doubtless often are, caused by variations in the environment in different localities. Thus epidemics of collar crack in cacao may occur in one place but not in another, and the varying conditions of the respective localities account for this. Similarly, among conifers it has been found that in the presence of an abundant development of the fungus a species may be attacked in one place but not in another. Thus within the writer's experience Japanese larch is resistant near Oxford during the first few years after planting, but has proved to be very susceptible in Shropshire. The unknown cause of this is almost certainly some difference between the two localities in environmental conditions. Of equal interest are the variations in susceptibility occurring in a species in any one place and during one rotation. Thus Hiley (12) refers to the increase in susceptibility of larch at about the age of 15 years. Changes in susceptibility have also occurred in the experimental plots in Bagley Wood, Oxford, referred to by him. The Sitka spruce have ceased to die even though in one or two cases trees are known to have roots infected with the fungus. In the Corsican pine, where only one tree had been killed, a considerable number have been lost, but since the plot has been thinned, both officially and accidentally by fungus, the rate of death has slowed up and the attack is apparently stopped. In the Norway spruce two have died, but others have been attacked, yet still live and grow apparently

without check. The high death-rate in the Weymouth pine has not been kept up. One of the Douglas fir and many of the *Thuja plicata* and *Tsuga heterophylla* have been infected but not killed. In the case of *Thuja*, *Tsuga*, and larch, infection has occurred subsequently to dry periods in 1919 and 1921 and appears to be secondary to damage by drought.

These few examples will be sufficient to show that even where the fungus is abundant, as everywhere in Bagley Wood, the susceptibility of any one species is not constant in degree over any length of time but varies with comparative frequency. This undoubtedly points to something external to both the host and the parasite which controls susceptibility otherwise, as in the case of Sitka and Norway spruce, infected trees would not die on one occasion and not on another. It is also confirmation of Hiley's statement that 'if perfectly healthy roots were liable to be penetrated by the rhizomorphs, I do not think that such immunity (to infection on the part of various species) could have been expected' (12).

Very important for this discussion is the conception of what a perfectly healthy root is. Usually it is considered that any root is healthy that belongs to a tree that as a whole appears itself so to be. This is, however, not of necessity true, and an example may be quoted in illustration. Two Corsican pine occurred in Bagley Wood, both with rhizomorphs growing in the thick bark at the root collar. The one was a dominant tree and very vigorous. It had not been infected and there were no signs of attempted attack. The other tree grew on similar soil and only a short distance away. It appeared to be healthy, but was just becoming dominated by the surrounding trees. This tree was discovered to be quite recently penetrated by the fungus through uninjured cork layers. The probable explanation is, of course, that the tree had become debilitated owing to its inferior position and so was unable to resist infection. This explanation, however, introduces a more refined conception of a state of disease, for if the tree had become debilitated, this state of debilitation was not merely a condition predisposing the tree to infection but was in itself a state of disease. Once this conception is realized it can be seen that susceptibility to infection may be the result not merely of catastrophies such as drought or being planted in an excessively wet soil, but that less obvious things may bring it about. In this way the number of possible adverse factors that might arise in the environment of the plant are, quite apart from possible variations in the inherent resistance of the host or in the virulence of the fungus, sufficiently great to account for all variations in susceptibility that might occur.

CONCLUSION.

It is now possible to attempt to answer the questions asked during the course of the discussion. First, is the fungus really a parasite infecting healthy trees? While there is no proof that it never does act in this way, all the evidence goes to show that it is always secondary to some other factor acting as the primary cause of disease. If the fungus is a parasite of a secondary nature, what are the

factors predisposing the trees to its infection and bringing about the initial state of disease? It has been shown that in many cases these are adverse soil conditions acting alone or in conjunction with others such as defoliating larvae or infection by mildew. Sometimes the latter may of themselves cause susceptibility. These initial causes of disease are not always obvious, but it is to be presumed, in lack of evidence to the contrary, that they are always there when trees become infected. It remains to ask why it is that the fungus appears to so great an extent as the apparent primary cause of disease in artificially regenerated forest or plantations. Once it is granted that the fungus is always acting in a secondary role, this question needs to be asked no longer. The difference between natural and semi-natural forest and that artificially regenerated is that in the one case the primary cause of disease appears usually to be some obvious thing such as drought or defoliation, while in the other it is more difficult to observe and so more frequently remains undetected. What is needed, then, in order to come to a greater understanding of the origin of susceptibility to root-rotting fungi such as *A. mellea* is a greater knowledge of the reaction of the forest tree to its environment. In times when new species are constantly being introduced in many parts of the world and grown for economic purposes outside the range of their natural distribution this is particularly necessary, for much of the disease that affects such species is caused by nothing more than a failure to realize what are the conditions necessary for their healthy growth.

The importance of understanding what is necessary for the health of the crop is so obvious that it should need no stressing. The subject is, however, so large that it is only by degrees that a proper comprehension of it will be obtained. Nevertheless, it will in the meantime be an advantage if it comes to be increasingly understood that the study of forest disease is not a pure mycological or entomological matter, but that it is, as a whole, based on an understanding of the life of the forest and especially on the normal and pathological physiology of the individual trees. Health or disease involve a particular way of life, that is for the tree particular conditions for growth, and while it may in some cases pay to grow crops that are unsuited to the conditions within which they grow and to protect them artificially against disease, in forestry this will not usually be so. Everything depends, therefore, in having a crop that is really suited to its environment, and it is in endeavouring to determine what this is that the pathologist and silviculturist meet and real progress is made in the control of forest disease.

REFERENCES

(1) Arnaud, G. et Mme: 'Notes de pathologie végétal. III.' *Rev. Path. Vég. et Ent. Agr.*, xi. 3, 178–82, 1924.

(2) Berger: 'Ist der Hallimasch Parasit oder Saprophyt.' *Forstwiss. Centralbl.*, 1922, pp. 424–31.

(3) Butler, E. J.: 'Report on some Diseases of Tea and Tobacco in Nyasaland.' *Dept. of Agric. Nyasaland*, 1928.

(4) Craighead, F. C.: 'Studies on the Spruce Budworm (*Cacoecia fumiferana* Clem.),' Part II: *Dom. of Canada Dept. of Agric. Bull.*, No. 37, New Series.

(5) Dade, H. A.: 'Collar Crack of Cacao (*Armillaria mellea* (Vahl) Fr.).' *Dept. of Agric. Gold Coast Bull.*, 5, 1927.

(6*a*) Day, W. R.: 'Parasitism of *Armillaria mellea in Relation to Conifers*.' *Quart. Journ. Forestry*, Jan. 1927.

(6*b*) Day, W. R.: 'The oak mildew *Microsphaera quercina* (Schw.) Burrill and *Armillaria mellea* (Vahl) Quél, in relation to the dying back of oak.' *Forestry*, 1927, pp. 108–12.

(7) Eklund et Wenmark: 'Några undersökninger av aspskog.' *Skogvards Föreningens Tidskrift*, 23, 80–104, 1925.

(8) Frömbling, C.: 'Vom Honigpilz.' *Forstwiss. Centralbl.*, 1915, pp. 299–304.

(10) Geschwind, A.: 'Das Vorkommen des Hallimasch (*Agaricus melleus* Quél) in den bosnisch-herzgowinischen Wäldern.' *Nat. Zeit. f. Land- u. Forstw.*, 1920, pp. 182–6.

(11) Hartig, R.: *Wichtige Krankheiten der Waldbäume*, Berlin 1874.

(12) Hiley, W. E.: *The Fungal Diseases of the Common Larch*, Oxford 1919.

(13) Hole, R. S.: 'Mortality of spruce in the Jaunsar Forest, United Provinces.' *Indian Forester*, 1927, pp. 434–43 and 483–93.

(14) Kusano, S.: '*Gastrodia elata* and its symbiotic association with *Armillaria mellea*.' *Journ. Coll. Agr. Imp. Univ. Tokyo*, vol. 4, p. 1, 1911.

(15) Miège, M. E.: 'Note préliminaire sur les principales maladies cryptogamiques observées au Maroc.' *Bull. Soc. de Path. Vég. de France*, 1920, pp. 37–40.

(16) Nechleba: 'Das Hallimasch.' *Forstwiss. Centralbl.*, 1915, pp. 384–92.

(17) Neger, F. W.: 'Das Tannensterben in den sächsischen und anderen deutschen Mittelgebirgen.' *Thar. forstl. Jahrb.*, 1908, pp. 201–25.

(18) Oppermann, A.: 'Granskovens Sundhedstilstand paa Forsøgsvæsenets faste Prøveflader.' *Forst. Forsøgsv. Danmark*, 1922, pp. 23–86 (French summary).

(19) Schmitz et Jackson: 'Heartrot of Aspen.' *Univ. of Minnesota Agric. Exp. Stat. Tech. Bull.*, 50, 1927.

(20) Spaulding et Gravatt: 'Conditions antecedent to the infection of white pines by *Cronartium ribicola* in the North Eastern United States.' *Phytopath.*, 1925, pp. 573–83.

(21) Wiedemann, E.: 'Hallimasch und Wurzelschwamm zwei gefährliche Waldfeinde.' *Biol. Reichsanstalt Land- u. Forstwirtsch.*, Flugbl. 22, 1924.

(22) Zeller, S. M.: 'Observations on infections of apple and prune roots by *Armillaria mellea* Vahl.' *Phytopath.*, 1926, pp. 479–84.

SILVICULTURAL RESEARCH IN INDIA; ITS ORGANIZATION, PROBLEMS AND METHODS

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I. ORGANIZATION.

SYSTEMATIC research into silvicultural problems in India has recently attained its majority, so the present time is an appropriate one for review of past progress and consideration of the future. This does not mean that such research was previously non-existent, as a perusal of the contents of the *Indian Forester* (founded in 1875) will rapidly satisfy the inquirer; but it was not generally realized how vast is the difference between random investigations by the 'professional amateur'—if the term may be allowed—and organized research by the whole time research worker. Our forests are full of the vestiges (many not even recognizable or remembered as such) of abortive experiments, very commonly started with the greatest care and enthusiasm, but not carried through to successful conclusion, usually through no fault of the originator, but through the usual exigencies of service involving periods of absence on leave and not infrequent transfers. The forest takes a long time to answer the questions put to it, and if not watched is very prone to turn to side issues or to different questions altogether; and to get what he wants, the inquirer must be very insistent, he must stick very rigidly to the point, and he must be ready on the spot still with the same question at the psychological moment when the forest is ready to give the long awaited answer. To illustrate from the simple case of a plantation under average Indian conditions. Failure may result at any stage, from even before the seed or plants are in the ground (through inadequate preparation of the soil), to several years after (through inadequate cleaning or protection), and success can only be claimed at best 4 or 5 years later, often 10 or 12 years later. Under ordinary conditions as affecting the officer in charge of a territorial division, more usually than not he cannot see such a plantation experiment through to 'establishment'. His successor, to whom he has to hand it over for the final stages, is usually new to his surroundings and is too fully occupied in getting acquainted with them and in doing the year's routine initial works to give the older areas the attention they need, even if he has the necessary experience. This being the case with straightforward plantations, how much more difficult is the solution of natural regeneration problems, which have proved so stubborn even to organized research.

In two other important respects, the older random experimental work was—admittedly with certain fine exceptions—barren. One was the almost universal absence of adequate written records. A keen territorial officer, after a year or

two in a divisional charge, would realize the need of solving a certain local problem, and do the necessary initial work of measurement, enumeration, laying out experimental plots, or whatever the problem called for. For several years he would watch developments and then would come leave or transfer. Very rarely could he take his successor to the spot, and very rarely did he write up a final note; in any case, he was unable to impart to his successor either the experience gained to date or his enthusiasm for that particular half-completed experiment, and in due course it would get forgotten or be pronounced a failure. A typical case may serve as illustration—a series of plots laid out in almost faultless style to follow the effects of unrestricted grazing on the regeneration of a certain species. When these plots were handed over to a research branch on its initiation 4 or 5 years later, it was found that there was no record whatever of the amount, size, or condition of the regeneration existing in the plots when they were first laid out, although a good deal certainly did exist.

The other defect referred to is closely connected—was in fact the cause of that described in the foregoing paragraph. It was the lack of experience or training in research methods, the lack of the research outlook, on the part of those doing the work. There is undoubtedly still a widespread feeling that any one can undertake research, in fact examples could unfortunately be quoted (but will not be!) where failure in executive or administrative posts has been the qualification for posting to a research billet, if on no better grounds than that the possible continued failure will do less harm. The impression must not be gathered that this has been the universal custom in India, for many provinces have definitely selected the best man they had for research work, even when he could ill be spared, but elsewhere there is still room and need for an improved outlook. However, it has still to be admitted that even the best men available, with rare exceptions, have not had any special training in research methods, and have had to feel their way with a minimum of assistance and inevitable waste of time and effort to the best procedure—the more credit to those who have succeeded in doing so, it will be agreed.

From this rather lengthy introduction, we may turn to an historical survey of the organization of silvicultural research work in India and Burma. The first research post sanctioned was that of Imperial Silviculturist at the newly constituted Forest Research Institute at Dehra Dun in 1906. A post of Imperial Superintendent of Forest Working Plans was created at the same time, and was filled in the same year, but the silvicultural post was held by the Principal of the Institute and (training) College, simultaneously with his other duties, an arrangement which obviously could not permit of intensive study of even one big problem. In 1909 the two posts were combined; Mr. R. S. Troup was appointed and made a real start. Conditions remained virtually unaltered till the first provincial appointments in 1916 (Burma) and 1918 (United Provinces), so that for nearly a decade there was only one full-time silvicultural research officer for the whole 104,000 square miles of State forests of India proper apart from Burma.

Under the circumstances, the only course open to the Imperial Silviculturist was to select outstanding problems from the vast field before him, and to put them on a proper footing, and this is what was done by successive incumbents of the post. At the same time, the obvious duty lay before them to collect all useful information already on record or otherwise available, and to compile it as a starting-point for subsequent work; this also was done.

During the decade in question, especially under the great stimulus of war demands and conditions, the utter impossibility was realized of a single officer's conducting research scattered over such an enormous area as India, not to mention Burma. Actually, statistical sample plots and experimental regeneration plots were laid out by the Silvicultural Branch of the Forest Research Institute in seven of the ten major provinces, but their maintenance from Dehra Dun was hardly a practical proposition from the start except in the nearer localities of the United Provinces and the Punjab.

As might have been expected from its isolation and remoteness from Upper India, it was Burma which first experienced the unquestionable necessity of a special local research officer. In 1916, a picked man was appointed, and from that date invaluable work has been done with periodically increasing staff. Two years later, in 1918, the United Provinces followed suit, though the first problem undertaken was as much economic as silvicultural, being a survey of the resources of miscellaneous timber species of the province. Bengal and Madras made similar appointments in 1919, Bihar and Orissa in 1921, the Central Provinces in 1922, and Assam in 1927. Only Bombay (annual forest surplus £247,500) and the Punjab (£90,000) are left without whole-time posts, and the latter at least is contemplating action in the matter.

It will be apparent that the appointment of provincial research officers has altered very fundamentally the position and function of the Central Silviculturist at the Forest Research Institute. With existing provincial administration and increasing autonomy, it is impossible—and on almost all grounds equally undesirable—that the Central Silviculturist should exercise any sort of official control over Provincial Silviculturists, and it is fairly clear that the really valuable sphere of activity for him to fill is that of ensuring co-ordination, the use of up-to-date methods and latest information, and of supplying advice or other help from his wider experience and facilities, as requested by his colleagues in the provinces. This question of the relation between central and local silviculturists is perhaps a somewhat delicate one, and one which requires constant adjustment to changing conditions; it is one which is greatly helped by open discussion and so has appeared on the agenda of the two Silvicultural Conferences which have been held since it arose. The present position was redefined in a resolution passed by the last conference (1929), which may be reproduced as comparable conditions are likely to arise in other parts of the empire. The very satisfactory relations existing are illustrated by the fact that this resolution was in all respects and almost verbatim the recommendation of the Central Silviculturist.

RESOLUTION I (*a*). *Resolved that this Conference accepts the report of the Committee recommending the adoption, with certain modifications, of the Central Silviculturist's proposals.*

REPORT OF THE COMMITTEE.

The committee recommends that the relation of the Central Silviculturist to the Provinces be further defined as follows:

I. Statistical

1. The Central Silviculturist should continue to undertake all sample plot calculations as a routine measure.

2. The Central Silviculturist should investigate thoroughly methods of forest statistical research, and make proposals for consideration where the need is felt for collection of data.

3. The Central Silviculturist should arrange to give assistance in the field to Provincial Silviculturists on application from them, and thereby keep his staff in touch with forest work.

4. The Central Silviculturist should undertake compilation of yield and volume tables or any other similar work in which help is required by the provinces. If a province wishes for any reason to do such work itself, the connected records at the Research Institute should be made available for the purpose. The Central Silviculturist should also propose a standardized procedure for such operations as lend themselves to it; a revised and extended Statistical Code is required for this. Resolutions would be passed on these matters at the periodical Silvicultural Conference.

II. Experimental

5. The Central Silviculturist should make a special study of methods of experimental research and circulate useful information collected. A general guide for the conduct of experimental research on silvicultural problems would be very helpful to research officers in the provinces. It should advisedly include, as a separate part, prescriptions for procedure and for the use of forms where their introduction would be definitely helpful and not a hindrance to individual initiative.

6. The Central Silviculturist should see provincial experimental plot files annually, as far as this is practicable,[1] to enable him to maintain his records up-to-date, and should record any comments or suggestions he may desire for consideration by the Provincial Silviculturist. He should pay special attention to co-ordination of work and co-operation between provinces in problems affecting more than one province.

7. The Central Silviculturist should similarly see as many of the provincial experimental plots as possible. He should also see other investigations with the same object.

8. The Central Silviculturist should undertake such original investigation work as he can usefully attempt under Dehra Dun climatic conditions and with such assistance as he can be given. Such work should as far as possible be selected from among proposals received from the provinces.

9. Under special conditions, the Central Silviculturist might arrange with the provincial authorities to initiate if not maintain special investigations in a province where the need for them was felt by either party.

The Committee also reports with regard to the staff of the Central Silviculturist, that it considers that requirements must depend on the extent of the help asked for by

[1] Cf. Resolution l.c.

provinces under Heads 3 and 9, and it appears that a good deal of help may be asked. It is not found possible to do more than to recommend that the Central Silviculturist's trained staff should be maintained up to the strength found necessary by him to undertake such work.

The matter was further considered by a special committee appointed in 1929 by the Government of India to inquire into the organization, working, and control of the Forest Research Institute. Their report has not yet been published, but it is understood that it will endorse these views in its recommendations.

It is necessary next to consider the organization in the several provinces. The close connexion between working plans and research has always been recognized, and realization of the importance of having the best possible working plans, revised at relatively short intervals, has led to the appointment of a senior administrative officer as Conservator of Working Plans and Research in the United Province (1920), Burma (1921), and Madras (1925). In the Central Provinces, the Superintendent of Working Plans (1925) is not yet a conservator's post, and in the Punjab (1921) both working plans and utilization are combined under one conservator, the province being relatively small and utilization work relatively straightforward. In all these cases, the Silviculturist works under the Working Plans Conservator, and elsewhere directly under the Chief Conservator or Conservator.

As regards staff, conditions naturally vary considerably in the several provinces. The 1929 Conference passed a resolution that the minimum staff required to enable the Silviculturist to work efficiently was one sample plot field party consisting of one Provincial Service Officer or picked Ranger (who has had 2 years' special training at a Ranger's College), 3 Foresters (sometimes

Province.	*I.F.S. Assistants.*	*P.F.S. Assistants.*	*Rangers.*	*Dy. Rangers.*	*Foresters.*	*Clerks.*	*Annual cost Rs.*	*Notes.*
Bengal	..	1	1	..	1	2	19,300	
Burma	1*	1	3	4	10	(2)	51,000	*sanctioned.
Bihar and Orissa	1†	1	1	1	1	..	20,300	†for training.
Central Provinces	..	..	..	1	..	2	12,800	Costs include salary and allowances of the Silviculturist.
Madras	..	..	2	..	..	2	21,000	
United Provinces	..	1	1	..	2	5	27,000	
TOTAL	2	4	8	6	14	13	1,51,400	

Say £11,300

specially appointed when commonly educated to matriculation standard, sometimes passed through a 6 months Foresters' course of training), and two clerks. Actually, in most provinces the staff is greater as shown in the table for 1928 (on previous page), and on the whole, additional staff has usually been sanctioned as required when the work has expanded and the Silviculturist concerned has justified his existence.

The staff of the Central Silviculturist consists of:

1 Imperial Assistant (not yet appointed).
2 Provincial Assistants (on deputation from the provinces and in charge of statistical and experimental sections respectively).
1 Head Computer } for statistical work, mainly in connexion with sample
4 Computers } plots, in office and forest.
5 Field Assistants.
3 Artists and Photographers.
1 Seed Collector.
4 Clerks.

The total expenditure on this staff, including the Silviculturist himself in 1928/29, was Rs. 34,400, say £2,600.

* * * * * * * *

Procedure as regards the programme of work undertaken differs. As a rule, suggestions as to what investigations are most needed are collected from territorial conservators and divisional officers, compiled and sifted out, and a programme drawn up for the approval of the Chief Conservator or other administrative officer concerned. Sometimes the Silviculturist draws up a programme in consultation with the Conservator of Working Plans, and it is considered at a meeting of senior officers. Such programmes are generally for a short period of years, 3 or 5. The suggestion has been made, which seems to meet with general approval (including that of the Government Committee referred to above), that provincial programmes should normally be submitted to the Central Silviculturist for his comments—suggestions for amendments in the light of what has been done or is being done in other provinces, and additions if co-ordinated attack on some problem of more than provincial importance appeared advisable. To some extent, this is done unofficially already, and it may become a routine matter.

In connexion with programmes, it may be advisable at this stage to revert to that of the Central Silviculturist. At the moment matters are in a stage of flux, but existing arrangements provide for the compilation of a draft triennial programme of work by the Central Silviculturist, which is circulated to provinces for suggestions. The suggestions received are duly considered and incorporated as far as possible, after which the programme is submitted to the Board of Forestry, an advisory body of senior officers constituted in 1910 to consider the management and work of the Institute under the presidency of the Inspector General of Forests. Political and other changes have resulted in the suspended animation of this Board, and it is uncertain what the

organization will be in future. Actually, the programme of research is now so narrowed down that it is virtually capable of definition once and for all pending further reorganization.

An account of the organization would not be complete without further reference to the periodical silvicultural conferences which have been held to discuss matters of common interest. That such conferences derive their chief value from the personal contacts made is now so widely realized that it requires nothing more than mention. Three such conferences have been held in 1919, 1922, and 1929, and all have been productive of valuable results. Thus the very rapid progress made in the statistical study of crop increment of gregarious species in even aged forest was the outcome of the general adoption of the standard procedure brought forward at the earlier conferences, and the far-reaching resolutions of this year's conference are already showing signs of bearing fruit though the print is barely dry.

In conclusion of this section of our subject title, mention should be made of the expenditure incurred on silvicultural research both by the Central and Provincial Governments. The last column of the statement concerning staff given above shows the approximate sum spent in 1927/28 on the Provincial Silviculturists' salaries, staff, and allowances, totalling £11,300. To this should be added £2,600 spent similarly at the Forest Research Institute, making a total of £13,900. Expenditure on work and materials cannot adequately be assessed, as accounts are sometimes included with those of Working Plans or General Direction, and sometimes charged to divisions. There are grounds for putting it at about one-quarter of expenditure on staff, £3,500, bringing the total up to £17,400, which may be compared with £4,640,000 gross and £2,000,000 net forest revenue in the previous year. No addition has been made for the Conservators, but if it be estimated that about one-fifth of their time goes to supervision of research work, a further £2,000 expenditure approximately, should be included.

The position of the Divisional Forest Officer with regard to research in his division has several times come up for consideration, particularly where there has been a Silviculturist for some years. The principle is generally realized and acted on that the Divisional Forest Officer should be kept fully informed of what is being done and the reasons for it, and as the suggestion that the investigation should be undertaken often comes from him in the first place, his advice and local experience is sought whenever possible. The difficulty encountered has been as to how much help in the actual work and recording should be asked, and after fluctuations towards both extremes of every thing and nil a compromise has usually been reached. As a rule, it is advisable that the Silviculturist should be responsible for all measurements and recording, but he cannot be all over the province at once, so where the Divisional Forest Officer is in a position to do this work and is willing, he may be asked to do it. Similarly, if any Divisional Forest Officer presses the need for research in his division which cannot be included in the Silviculturist's programme, the Divisional Forest Officer undertakes it himself in consultation with the Silvi-

culturist who has to follow the records and see that the methods and application meet scientific research requirements. In this connexion it should be mentioned that the lesson has been learnt that scattering the work too greatly leads to dissipation of energy, and a preliminary period of widely dispersed investigations has usually resulted in concentration in a restricted number of selected typical areas, urgent problems elsewhere being taken up by Divisional Forest Officers as just mentioned. Similarly, as each new plot is laid out necessitating future periodic inspections, care has to be taken that it will be possible to return to it for the purpose in addition to disposing of work already in hand —neglect of this has in some cases necessitated a drastic revision of the whole programme of work.

II. PROBLEMS.

The problems before the silvicultural research worker are, in general terms, the same in all countries, variation being introduced by the degree of complexity in which they present themselves, and their relative importance. Four main types are conveniently distinguished, though they are closely interconnected and freely overlap. These are

(i) Natural Regeneration.
(ii) Artificial Regeneration, including Afforestation.
(iii) Physiological and Ecological Problems.
(iv) Production Statistics.

The problems provided by natural regeneration are unquestionably the most complex and difficult to solve. Leaving to one side coppice regeneration, which is practised over very considerable areas in India, it must be admitted that on the whole we have not made the progress we ought to have made in the 63 years of our existence as an organized service in India. Even in the areas pointed out as examples of eminently successful seedling regeneration, it is commonly the case that regeneration occurred spontaneously rather than by design, as a result of general protective measures rather than intentional regeneration operations. Our commonest pine (*Pinus longifolia*), and under certain conditions only, deodar, present no difficulties, but blue pine (*P. excelsa*) in pure crops, deodar in many localities, spruce in most places, *sal* (*Shorea robusta*) in much of the better quality soils, and teak over much of its range have all proved so difficult to regenerate to order, that one must predict that a considerable period of years must yet pass before the work can be undertaken with full confidence of success. Our extensive mixed forests present similar difficulties, and plenty of examples exist where we are, with our eyes open, felling overmature stock with no young growth whatever to replace it.

Thus we all have natural regeneration problems under study, the fortunate ones perhaps only with two or three species, the less fortunate (perhaps the enthusiast would write, the more fortunate), with a number of types many of them of a most complex nature involving the interaction of at least tens of species. How these problems are being tackled or avoided will be discussed in the next section.

Artificial regeneration has made tremendous progress in the last decade or so. Plantations have been made since the days of our pioneers, by such men as Brandis, Schlich, and Gamble, and even before their time (e.g. the Nilambur teak plantations initiated by Conolly in 1844), but they were of insignificant extent in comparison with the gross areas involved. The really big expansion came with the realization that in the much abused shifting cultivators, a force lay to hand which, directed into the right channels, was capable of improving the yield capacity of our forests on a scale proportionate to the destruction it had wrought in the past. Burma, of course, led the way and has given the name *taungya* (= hill clearing) to the method, but later it has been widely copied, notably in Bengal, and where the actual cultivators are unobtainable, the technique has been adopted to local conditions for ordinary plantation work.

Exact figures are not available, but approximately 30,000 acres were regenerated artificially in the 1926 season, bringing the total area up to approximately 318,000 acres for ordinary plantation work, with an additional 7,450 and 155,000 acres respectively for *taungya*.

In several divisions 500 acres annually is a common figure, and it should be remembered that this is not just the question of the planting up of such an area of waste land more or less devoid of tree growth handy to centres of population and lines of communication, but more generally one of a relatively inaccessible tract of dense forest from which the commercial timber has first to be extracted and then the dense tangle of unexploitable trees, creepers, and bamboos systematically cleared and burnt by a definite date, before real plantation work can be commenced. Developments being so recent, investigations into the problems of details of method, species to be used, spacing, mixtures, cleaning, underplanting and early thinning are still mostly under way. Fortunately the initiation of large scale work came at about the same time as the introduction of organized research, and improvements are now systematically sought for and tested on scientific lines, and promising results promptly confirmed and applied generally if reliable. So far, again speaking in general terms, we have tended to rely too much on a very few species which have been put out wholesale without all the consideration desirable as to whether they were always the best suited to locality and conditions. There is usually an obvious economic reason supporting this procedure: thus teak is commonly three times as valuable as any other species which might be grown, and it may even be the only species likely to be valuable enough to pay for extraction; similarly in their own localities for deodar and for *Shorea robusta*. Another tendency which was often to be noticed is the preference given to species which are relatively easy to raise. Recently this matter has been receiving, at least in some provinces, the attention it requires both from economic and silvicultural grounds, and special studies are being made of the species suited to the varying soil and climatic factors encountered, and conversely of the requirements of the several species worth growing. We are perhaps now more prepared to gamble a little in futures, and put in a second-class species which will grow well even if its present sale value is low, where formerly we would have put in, say, teak knowing only

poor growth was possible, but arguing that even fourth-quality teak would pay better than high-quality anything else.

We have our purely afforestation problems too, above all in the Punjab canal colonies. Here experience acquired in the last 53 years in the well-known Chhanga Manga (1866) plantation stands us in good stead, but a vast amount of work remains to be done in determining maximum economy possible in water requirements, optimum treatment for different types of saline soils, most economic initial spacing, and so on. Yet another very important field, in which much has been done but vastly more remains to do, is the reclamation and afforestation of denuded and eroded ravine lands, as well as of the enormous areas of sandy and saline waste which exist in many parts of the country. Nursery work is capable of much improvement and partial standardization in most provinces would be an advance.

Mention of these matters leads easily on to the third type of problems for investigation—tree physiology and ecology. If the reader will reflect on the volume of literature for oak, beech, spruce, or Scots pine, on the amount of research in progress on each of them, and then remember that in India our timber tree species run well into four figures, he will gain some idea of the magnitude of our task—and he should remember to use geometric not arithmetic ratios in his mental calculations. Actually, conditions force us to view some of our forest types—our rain forest, our mixed deciduous forest, and so on—as though they were species, which is quite logical, but can of course only be a temporary measure. In this direction the Silviculture and Botany branches of the Research Institute come into close contact, and a post of Ecologist has long been sanctioned in the latter, though as no suitable officer has been forthcoming it has not been filled. There is a host of primarily ecological problems awaiting solution in connexion with natural regeneration alone, and at present we have not a single officer trained for it either at Dehra or in the provinces.

The closely connected soil problems have been better provided for, as the Institute staff has always included a chemist ready to undertake such soil work as was required, but the greater part of his time has been devoted to economic products; and our forest research staff generally have known too little about the soil and the great development of recent years of soil science to make much use of the services of an expert pedologist. However, we have investigations in progress in connexion with the relation of saline soils to growth in plantations in the canal colonies, and the changes wrought in different soils by afforestation with different tree species, as also with the soil moisture conditions at different depths in relation to survival over drought periods. Investigations have also been undertaken concerning the use of manures in nursery work and the effect of heavy grazing and burning on forest soils.

Among the physiological investigations, we have again the water requirements and water consumption in irrigated plantations, and the 'establishment period' for the seedlings of several important species could usefully be studied. In this connexion also, research on root competition should shed much light on ill-understood vagaries in development of natural regeneration and plantations.

Lastly we come to the group of problems comprehended under the term 'production statistics'. This work, primarily mensuration, is by common consent relegated to the Silviculturist, and in India at least has hitherto formed almost too large a proportion of his work. The attitude has tended to be that the divisional officer was quite competent and ready to grow his own trees and regenerate his forests, but was equally ready to let the research officer amuse himself with figures and undertake the tedious and lengthy task of determining just at what rate the forests were growing. The satisfactory progress made in this direction has already been referred to above, for we now have crop yield tables on standard lines for all our major *gregarious* species—*Shorea robusta*, *Cedrus Deodara*, *Pinus longifolia*, *P. excelsa*, and *Dalbergia Sissoo*. For teak we have very useful tables prepared for Nilambur which await recalculation on the subsequently standardized lines and expansion to include other provinces, notably Burma: for the Nilambur teak also we have the only money yield tables hitherto compiled for India. The tables are, of course, all subject to revision, nearly 1,000 sample plots being maintained to that end.

However, these yield tables only touch the fringe of the problem of the collection of growth statistics, since only some 1,600 square miles of our total area (= 0·007 per cent.) are actually under uniform systems. Enumerations combined with stump analysis and rough volume tables have still to serve for practically the whole area, and whilst the preparation and steady improvement in our Working Plans is doing away with much of the old guess work, methods of dealing with this set of problems are under close scrutiny and consideration. Meanwhile steady progress is maintained in the compilation of general (single tree) volume tables and collection of form factors and similar data. The special problem of age determination of trees and crops of species not forming annual rings may be alluded to, and prospects exist of a serviceable solution being reached.

The bulk of the field work must be and is being done by the research workers in the provinces, but that plenty falls to the Research Institute is illustrated by the headings of the current programme, which are as follows:

I. General.
   1. Ledger filing: dissemination of silvicultural knowledge, scrutiny of silvicultural sections of all Working Plans.
   2. Afforestation of 200 acres of 'demonstration forest'.

II. Statistical.
   3. Compilation of yield tables for 19 species.
   4. Tree Volume and Increment data for 30 species.
   5. Compilation of money yield tables.
   6. Investigation of methods of measuring and calculating tree and crop volume and increment.

III. Experimental.
   7. Investigations on seeds (whole field).
   8. Nursery and plantation practice.

9. Inheritance problems, soil indicators, causes of certain growth defects, &c.
10. Thinning investigations.
11. Regeneration problems (primarily methods of research).
12. Protection problems—erosion, weeds, &c.
13. Physiological problems—water requirements, root systems.

That this is not enough to keep the Central Silviculturist and his staff employed appears to be the view of the provincial research workers, as at the 1929 Conference referred to they requested him to undertake the following additional tasks.

1. Revise the Ledger Filing scheme and its index.
2. Prepare a manual of experimental research methods.
3. Write a new Code for all forms of statistical research.
4. Organize a co-ordinated investigation into the effect of the origin of seed of certain widely used species.
5. Collect and publish all available information on the problem of the pure teak plantation.
6. Collaborate with provincial officers in the classification of forest types.
7. Investigate methods of age and increment determination for species not forming annual rings.
8. Investigate methods of measurement of standing sample trees and various other problems connected with sample plots.
9. Propose methods of research into forest grazing problems.

It should also be remembered that one of the main functions of the Forest Research Institute is the ledgering of all available information as it appears, which bears on the wide range of forestry subjects which are relegated to the Silvicultural branch. Actually we have 1,050 specific and 280 general (subject) ledger files, as well as parallel photograph collections of 2,500 and 1,250 prints respectively.

III. METHODS.

It should have become clear from what has been written above that, with the outstanding exception of the sample plot procedure, lack of method has rather characterized our work in the past, though we were constantly feeling our way and making improvements. It has also been suggested that this has been primarily due to the fact that the work has perforce been carried on by men who have had no special training in research methods, who have mostly never seen anything of other forest research institutions, and who were not familiar with the literature emanating from such research stations. Perhaps the clearest illustration of this is provided by the very unequal results and progress made in different provinces according to whether the officers detailed to this work took kindly to it and rapidly qualified themselves for it, or not. It has not been the custom in the past to give forestry 'Probationers' any sort of introduction to the subject—they have had far too much to get through without it—and only the very few specially interested have been able to acquire it by special arrangement, so that even the Research Institute has only had an

extremely restricted field to choose from in filling its posts. In the provinces, the choice has been even narrower, usually nil, and it is not always or even generally feasible for men to be sent to Europe or even to Dehra Dun for special training. This situation was strongly represented to the Committee on the Research Institute and sympathetically considered. It was urged that the Central Silviculturist must be closely familiar with the methods in use and being developed in Europe, that officers likely to be considered for provincial posts should be sent to Dehra to acquaint themselves with the nature of the work and methods adopted, one at least being always posted there as Assistant Silviculturist, and finally that the Central Silviculturist, who must be an experienced and fairly senior officer, should normally be selected from among the Provincial Silviculturists.

Reverting to sample plot procedure, this has been adapted to Indian conditions from Schwappach's form factor method and standardized with excellent results. All the sample plots in a province have been handed over to the Provincial Silviculturist for maintenance as soon as one has been appointed, and he has ordinarily added considerably to the number. The field work is done by the provincial officer but the calculations are all done at Dehra Dun, and hitherto (but not of necessity) compilation of yield tables has also been done by the Central Silviculturist. One of the special modifications adopted in Schwappach's procedure is the introduction of an arbitrary distinction between timber (down to 8 in. diameter over bark) and smallwood throughout field work and computation, a matter which is open to a certain amount of criticism.

Methods for the collection of data for volume tables whether on the above-mentioned definition of timber, or for 'commercial' timber, are also standardized and give satisfaction. Such volume tables have been published both by the Institute and by provinces for a number of species including all those for which yield tables have been prepared.

A systematic survey of research methods for what is understood in India by experimental silviculture—really types (i) and (ii) of Section II above—has only recently been made, and still requires further development. The need of such a survey is generally felt, and recently found expression in a resolution passed by the 1929 Silvicultural Conference that the Central Silviculturist should compile a general manual. It is fully realized that this kind of research can never be conducted on rigid codified lines, as statistical research can and must be; but all workers consider that such a manual would be of considerable value to them, above all on first taking up silvicultural research.

So far, we have attempted to utilize for our own problems what we know of ecological and agricultural research practice, but we are not as familiar with it as we could wish, and realize there is much room for improvement.

Reference has been made to the former lack of adequate records, and this has been provided for by the introduction of standard forms to be filled in on the initiation of typical investigations, particularly experimental plots concerned with natural regeneration—and it has got home that adequacy usually does not connote large volume. The last conference approved a series of such forms

for use with each of the main common types of investigation, which should give much help in the desired direction by drawing the investigator's attention to all the matters which should be on record for the information both of the investigator making the observations, and of his successor who will have to draw the final conclusions; at the same time they are designed not to restrict in any way his freedom to conduct the investigation on whatever lines he finds suited to it, due consideration having been given to the lines suggested.

It was formerly laid down that all experimental plot files should be sent periodically to the Central Silviculturist for perusal and copying, but this has proved impracticable, whilst the submission of a full copy is admitted as wasteful of time and labour. The arrangement recently reached to keep the Central Silviculturist in close touch with the work in provinces is that a copy of the form giving all the initial information concerning an experimental plot, its object, the initial work done, and the procedure proposed, is sent in as soon as a plot is started, and later inspection notes of unusual interest as soon as made. If the Central Silviculturist considers on this information that he should see the full record, he can call for it, and some provinces still propose to send all files in once a year for his perusal and copying of important records. For other investigations comparable arrangements have been made suited to their nature and duration. It was also recommended that deductions drawn from experiments in the provinces should be referred to the Central Silviculturist for criticism before publication. The advice of the Central Silviculturist is frequently asked as to the most promising method of investigating special problems, and schemes are often submitted to him for criticism; he is expected to make suggestions if anything catches his attention in the records received.

In an earlier paragraph it was hinted that it has been found in some cases better to avoid certain very difficult problems rather than face them: this had reference to natural regeneration in several types of forest where clearfelling followed by plantation work, above all with *taungya* cultivators, has been the solution widely adopted and mainly responsible for the very large extension of artificial regeneration work in recent years.

CONCLUSION.

This note intentionally stops short of giving any account of the results obtained by the silvicultural research work done in India since it was first organized. The reason will be apparent from what has already been written, namely that the field is so vast and the problems are so varied that it would take us far beyond the compass of a short article to describe the problems, and the methods applied without which a mere statement of conclusions drawn would convey but little. Those interested are invited to refer to the Proceedings of the 1929 Silvicultural Conference, which will shortly appear, remembering that the papers and debates aim at contributing towards the solution of immediate problems under consideration at this time; no full account is given of what has already been accomplished, but the observant will note how often what is now proposed carries on from the foundations and rising superstructure built up in the previous years.

FOREST SOIL SCIENCE IN SWEDEN

BY G. V. JACKS
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THE foundations of Swedish soil science were laid by the work of 'Sveriges Geologiska Undersökning' in the middle of the last century. This institute carried out extensive investigations in the region of quaternary geology, and showed that the majority of the present-day soils of Sweden were formed by the action of inland ice during a late glacial period. The work of De Geer, in which he was able to fix the date of the melting of the last ice sheet by a study of the annual deposit of glacial and other clays, is well known. De Geer also determined the limits of the ice sea (marine limit), and explained the occurrence of glacio-fluvial sediments. One need only mention further the work of L. von Post, who has carried out important researches into the nature and history of the Swedish peat moors. He showed that an intimate connexion existed between the type of peat moor and the climate under which it was formed, and he originated the method of pollen analysis which has since thrown so much light on the historical development of the vegetation and forests.

Since the beginning of the present century, investigations connected with forest soils have been undertaken by Statens Skogsförsöksanstalt, an institute under state control, founded in 1902, in response to the growing demand for organized scientific research in all branches of forestry. At present the institute has three departments—forestry (silviculture, mensuration, &c.), entomology, and natural science (geology and botany). The present chief of the institute, Professor Hesselman, is also head of the science department, with which he has been associated from its initiation. He is assisted by a geologist, Dr. Olof Tamm, and a botanist, Dr. Carl Malmström.

Although the soil investigations of the science department are mainly undertaken with a practical end in view, they have involved a great deal of research of purely scientific value. The North Swedish forest region, especially, has been the subject of many intensive geological, hydrological, and ecological studies, chiefly the work of Drs. Tamm and Malmström. Compared with the north, the soil conditions in the south are much more complicated, and as yet have not been so thoroughly investigated.

The soils of the country are almost entirely derived from late quaternary deposits, from the last ice period, i.e., according to De Geer, 8,000 years ago in the south, and 14,000 years ago in the north. They consist mainly of chemically almost unweathered moraine and sedimentary material, originating from gneiss, granite, and porphyry. Only the fine clay particles have a composition which points to a chemical weathering during the last glacial period. In the south, and on the east coast, where the land lies below the level of the last ice sea, large areas of loam and clay are found. These soils are often highly fertile,

and the greater part of them is consequently under cultivation. Agriculture has also invaded the relatively small areas in south and central Sweden, where the soil has been derived from Silurian limestone. About 55 per cent. of the total land surface is under forest.

The main soil type is the iron podsol with raw humus, which attains its most pronounced form in the north, where hardpan is of frequent local occurrence. From a forestry point of view, the value of the iron podsol is largely determined by the water-retaining capacity of the soil, and by the biological properties of the raw humus. The former is mainly dependent on the content of fine particles in the soil, and therefore on the geology of the locality. In some places the presence of a hardpan, by inhibiting the too rapid percolation of water, is actually beneficial to forest growth. The biological properties of various raw humus types have been the subject of detailed investigation by Hesselman (see below).

Another variety of the podsol type, the so-called humus podsol, characterized by a more or less thick peat covering and by a dark coloured, humus-containing enriched horizon, is also found, almost always in connexion with a high ground water level. The ground vegetation tends to be richer in mosses (*Sphagnum* and *Hylocomium*) and poorer in herbaceous plants than that of the iron podsol. Humus podsol occurs most frequently on level ground, and is then rather unproductive, but occasionally it is found on slopes, where the ground water flows near the surface, and the subsoil is impermeable. It then carries the characteristic vegetation of the iron podsol, and is often highly productive.

Profiles with a very thick surface layer of peat (50 cm. or more) are sometimes found in North Sweden in connexion with a high level of stagnant ground water. The lower layers of the peat are generally quite impermeable to water, hence the normal leaching of the underlying soil is prevented. The leached layer is often imperceptible to the eye, though its presence can usually be detected by chemical analysis. These soils correspond to the 'ground water soils' described by Frosterus (1).

On slopes where the subsoil is permeable, a stream of running ground water can profoundly modify the prevailing podsol soil type. The normal raw humus layer disappears, and the soil profile approximates to that of the ordinary brown forest soil. At the same time the vegetation becomes more varied and luxuriant. The effect is much more pronounced when the ground water contains lime.

As the climate becomes milder towards the south, the tendency to podsolization diminishes, and in the most southern part of the country the climatic soil type is the brown forest soil. Large tracts of this region are under cultivation. The natural vegetation of the uncultivated parts is the beech forest, and to a lesser extent, oak, alder, and other deciduous trees. Even in the complete absence of lime, and when the soil has a mildly acid reaction, there are many localities where the brown soil type shows no sign of degradation to podsol. In other localities, raw humus accumulates readily, and the soil becomes strongly podsolized, especially under beech and sessile oak, or where the deciduous forest has been artificially supplanted by spruce. On the other hand,

there are distinct indications that under favourable conditions a soil, which has become podsolized under beech, can revert to the brown soil type if the beech is cleared and the ground is afterwards invaded by birch. The raw humus covering disappears, a ground vegetation of grasses springs up, and the original bleached layer is gradually replaced by a dark coloured soil, at the same time acquiring the definite, though somewhat undefinable 'crumby' structure characteristic of the true brown forest soil.

Large areas of Sweden are covered by peat moor, and a series of investigations is being carried out by Malmström at the Forestry Institute with a view to determining the conditions under which a moor can be economically drained for purposes of afforestation. Good progress has already been made in this direction, and much valuable information is now at the disposal of the forester to guide him in the choice of suitable land for draining.

Attention has latterly been directed to the question of the spreading of water-logged moors, which until recently were believed to be steadily encroaching on their surroundings, and rendering useless large tracts of previously fertile land. With a view to throwing some light on the problem, two moors, which appeared to show signs of rapid extension, were chosen for exhaustive ecological, geological, and hydrological study. As a result, a relationship was established between the occurrence of various plant associations and the local height of the ground water level. Similarly, the relation of the plant associations to the soil type was studied, and here again a close interconnexion was found to exist. A series of soil profiles taken from dry pine heaths and from the more and more swampy types of ground, showed a regular gradation from iron podsol to humus podsol, and further, in the dampest conditions, and under a thick peat layer, to the 'genuine ground water soil', which chemical analysis showed to be completely unweathered. The absence of weathering may be most simply explained by assuming that, from the time of the melting of the ice, the ground has always been covered by water. The regions where ground water soil occurs are thus the original waterlogged areas, and the assumed extension of moor has taken place around them. The question of the rate at which extension has gone on has been solved by Malmström by means of pollen analysis. It is known that the spruce first appeared in North Sweden about 4,000 years ago—considerably later than other indigenous species (e. g. pine, birch, alder). Hence, it may generally be assumed that those peat deposits which contain spruce pollen grains were laid down at a later date than those which do not. By mapping the areas in which spruce pollen grains are found in the lowest peat layers, an idea is obtained of the extension of the peat moor since the time of the invasion of the spruce. By this means it was shown that in the moors investigated the spread of the waterlogged areas has proceeded at a quite insignificant rate, and that the supposed danger of further rapid swamping is imaginary.

Perhaps the most important problem in Swedish forestry is that of securing satisfactory natural regeneration of pine and spruce under the severe climatic conditions of the north. It was with the object of throwing some light on this

problem that Hesselman undertook his now well-known work on the mobilization of humus nitrogen.

Hesselman's first paper, published in 1910, dealt with the difficulties met with in the regeneration of Norrland pine heaths. It was shown that the difficulties were not to be explained by the moisture conditions of the soil, by competition of shrubs, &c., or by other external factors such as snow break or damage by reindeer. Subsequent research led Hesselman to the conclusion that the source of the difficulties was traceable to the unfavourable nature of the raw humus layer. In 1917 he published a paper in which he showed that the success of natural regeneration was closely bound up with the mobilization, and, more especially, with the nitrification of the humus nitrogen; the slow transformation of humus in the north was the main obstacle in the way of regeneration. Field observations definitely showed that the best regeneration was always got on ground where nitrification was going on, though the presence of nitrate was not a *sine qua non* for the development of the young plants. Under exceptionally favourable conditions, nitrification goes on naturally in the humus or in the soil, giving rise to a vegetation of nitratophilous plants such as *Epilobium angustifolium* L., *Rubus idaeus* L., and *Senecio silvaticus* L. On such nitrifying soil regeneration is usually easy, provided that the tree seedlings do not suffer from excessive competition from the other plants. Normally in North Sweden, however, an external stimulus has to be applied to bring about an active mobilization of the humus nitrogen. Thus the increased access of light to the humus covering, brought about by fellings, has a strong influence on the transformation of nitrogen, resulting in an active production of nitrate, or, under less favourable conditions, of ammonia. The very beneficial effects on regeneration, so often observed after a forest fire, are to be ascribed largely to the rapid nitrification produced, as evidenced by the prolific growth of nitratophilous plants, which immediately spring up on the burnt areas. In general, also, such methods of working the ground as tend to mix the raw humus with the underlying mineral earth, seem to facilitate nitrogen mobilization. Hesselman suggests that the increased mobilization may be connected with the relative increase in the quantity of electrolytes produced by the above measures. The explanation, however, is purely hypothetical.

It was clear that the reaction of the humus layer to an increased light supply was conditioned by a large number of factors, both external, and intrinsic in the humus itself. Among the external factors, climate naturally plays an important role. It is difficult to separate its effect from the many other varying factors which influence nitrification, but in general it would seem that the warmer and drier the climate, the more readily does the humus react to an increase of light. The connexion between the mobilization of nitrogen and the intrinsic physical, chemical and biological properties of raw humus, form the subject of a paper published in 1927. Different types of humus were stored under identical external conditions, and nitrification was induced by inoculation with a nitrifying soil, by adding lime, or by a combination of both treatments. Great variations were shown in the amounts of nitrate produced by

different humus samples, but a general parallelism was observed between the ease with which the nitrogen in any sample was mobilized after increasing the light supply and after inoculating with nitrifying soil. Apparently one of the most important factors determining the mobilization of nitrogen is the amount of basic buffering substances in the raw humus. This depends largely upon the nature of the material from which the humus is formed, and hence upon the nature of the forest, e.g., upon its composition, age, and density. The leaves of deciduous trees are generally rich in basic buffer substances, and the beneficial effect on regeneration of their presence in a coniferous forest may be ascribed, in part at any rate, to this fact.

In his latest investigations (1927), carried out on somewhat similar lines, Hesselman has been able to show that a clear connexion exists between the development of young spruce plants and the mobilization of humus nitrogen. He was also able to demonstrate, in conjunction with Melin, a correlation between the good development of mycorrhiza and the ease of nitrification of humus in which the plants were grown.

Although Hesselman's researches have only embraced one side of the complex problem of natural regeneration in North Sweden, they have brought into prominence, and to some extent explained, the important role of the raw humus layer in the process. This has an added significance when it is remembered that the quality of the humus represents the main factor in a forest soil that can be influenced by man.

The numerous other researches carried out by the science department cannot be described in any detail here. Mention may be made, however, of a method worked out by Tamm (2) in 1922, for the analysis of the inorganic gel complex of soils. The method, which is based on the extraction of soil with acid ammonium oxalate, is widely used in Scandinavia. Although its application is limited to soils poor in clay, it has definite advantages over the hydrochloric acid method, and deserves wider recognition. The same author has lately published (in English) a suggestive paper on the experimental formation of clay from felspar (3).

The work of the science department during the last twenty years has already made itself felt in several directions in Swedish forest practice. Current views on such questions as forest drainage, the position of the birch in Swedish silviculture, the treatment of the ground after working, and the choice between clear cutting and selection cutting have all been influenced by the results of recent research. The successful application of these results to practice is largely made possible by the active and friendly co-operation which exists between scientific workers and practical men in all branches of forestry. The Research Institute works in close contact with the State College of Forestry, which is responsible for the training of the greater part of the personnel of the Swedish forest service, and members of the Institute's staff are often invited to give special courses and lectures to foresters, who are thus brought into personal contact with the latest results of research, and learn to apply them to their own particular problems. It may be said that while the Institute

has never set out to prescribe a definite silvicultural recipe, its aim and influence have chiefly been directed to building up a practice which shall imitate nature as closely as is compatible with economic considerations.

I take this opportunity to thank Professor Hesselman and his staff for their unfailing kindness and courtesy to me during the periods I was at the Swedish Forestry Institute in 1928 and 1929. I am especially indebted to Dr. O. Tamm, who personally supplied me with much of the information contained in this article.

REFERENCES

(1) Frosterus, B.: 'Zur Frage nach der Einteilung der Böden in Nordwesteuropas Moränengebieten.' *Geol. Komm. Finland, Geotekn. Medd.*, 14, 1914.

(2) Tamm, O.: 'Eine Methode zur Bestimmung der anorganischen Komponente des Gelkomplexes im Boden.' *Medd. fr. Statens Skogförsöksanstalt*, 14, p. 387, 1922.

(3) Tamm, O.: 'An Experimental Study on Clay Formation and Weathering of Felspars' *Medd. fr. Statens Skogförsöksanstalt*, 25, 1929.

AFFORESTATION IN SOUTH AFRICA

BY H. M. STEVEN

GENERAL POLICY.

IN the Union of South Africa, high forest, savannah, and scrub are met with in different parts of the country, but only the first type is important from a timber-producing point of view. This is a Temperate Rain Forest type, mainly evergreen, containing trees of more or less commercial importance, such as the coniferous species, *Podocarpus elongatus* Carr.[1] in part, not L'Herit., *P. Thunbergii* Hooker, and *P. falcatus* Sim., and broadleaved species such as Stinkwood *Ocotea bullata*, the Ironwoods *Olea laurifolia* and *O. capensis*, Assegai *Curtisia faginea*, *Nuxia floribunda*, *Platylophus trifoliatus*, and *Gonioma Kamassi*. High forest is localized, and is only found where the rainfall is considerable, generally over 35 inches. As in other countries the demand has been and is mainly for softwoods, and the forests have been worked through for *Podocarpus* spp. during the last century and more, so that the proportion of them has been much reduced. Of the broadleaved species, Stinkwood is the most valuable, being prized in South Africa as a furniture wood, while there is a small but steady export trade in Boxwoods, *Buxus Macowani* (Cape Box) and *Gonioma Kamassi*. The total area of high forest in the Union is about 1,042 square miles, compared with the total land area of 471,917 square miles. This is an abnormally low forest area, and as the present and potential production of softwoods from it is also low, the present annual cut being under half a million cubic feet, afforestation by softwoods is an urgent necessity. The forest policy of the Union Government is twofold, to maintain the indigenous forests, and to afforest bare land already in the possession of the State or purchased for the purpose, land suitable for afforestation being generally available at £2 per acre or less. The present programme of government afforestation is approximately 15,000 acres per annum, and the total area afforested up to the 31st March 1929 was 184,448 acres.

THE SERVICE.

The head of the Service is the Chief Conservator, whose head-quarters are at Pretoria, and who is directly responsible to the Minister of Agriculture. Under him there is a Professional Assistant, also stationed at Pretoria, and six Conservators, under whom are district officers each in charge of a group of forests, and assistant district officers. There is normally a European forester at each forest. The research staff is under the direction of the Professional Assistant, and it is stationed at Pretoria, with the exception of the research officer located at Deepwalls, Knysna, for the study of the indigenous forests in that region. There are at present over forty of the officer grade in the service. The

[1] The nomenclature in use in the Forest Department of the Union of South Africa is followed here.

method of recruitment is of interest; probationers are nominated from those who have already taken a degree in natural science at a South African University, and they then proceed overseas for their forestry training, the Universities principally favoured in the past being Edinburgh, Oxford, and Yale. The Service, therefore, has had a considerable variety of training. There is a school for the training of foresters at Tokai, near Cape Town.

GENERAL CONDITIONS OF ENVIRONMENT.

The principal limiting factor to high forest growth in South Africa is low rainfall. There are three types of seasonal rainfall: the Cape Peninsula and the south-western Cape Districts is a winter rainfall area; George, Knysna, and a narrow strip along the coast as far east as about Port Elizabeth has an all-the-year rainfall, and the rest of South Africa is a summer rainfall region. In most of the forest and potentially forest regions, as far as is at present known, the annual rainfall is between 20 and 50 inches per annum, and generally above the lower figure. The principal temperature feature is the comparative absence of frost; although it occurs in many forest areas, the temperatures are not low; hence a very wide range of species can be grown successfully. The south and eastern regions are warm temperate, and the northern Transvaal and Natal coast sub-tropical. Wind damage of the orthodox type does not appear important, but in the south a hot wind—the 'berg' wind—browns foliage.

Two of the most important afforestation regions, namely, the southern coastal fringe, including the Cape Peninsula and Knysna, and the Zoutpansberg region in northern Transvaal also differ markedly in geology, natural vegetative covering, and soil type. In the south, for example at Elgin, George, and Knysna, the underlying rock over most of the area is the Table Mountain sandstone, which, while variable, usually contains a large amount of quartz sand. The natural vegetation on this type of veld reminds one of the heaths in Europe, but it is much richer in families and species of plants. The following families are well represented: *Proteaceae*, *Ericaceae*, *Compositae*, *Cyperaceae*, *Bruniaceae* and *Restionaceae*. It is interesting to note that the quality of the land for purposes of afforestation and choice of species is assessed in part from the natural vegetation. The presence of *Brunias* and *Restionaceous* species indicates acid, poor conditions, where only the least exacting tree species will grow. The soil derived from the Table Mountain sandstone varies: in some instances, for example at Elgin, the soil is a white quartz sand without profile; but in the Knysna region the soil type generally shows leaching in the upper layers, particularly when *Brunias* and *Restionaceae* are present, and there is a layer of wet, acid humus. At Jonkersberg in this region a fully developed podsol was seen.

In the Zoutpansberg region where extensive afforestation is also in progress, at such places as Woodbush, de Hoek, and Entabini, the underlying rock is granite with numerous intrusions of dolerite, and similar rocks. The natural vegetation is typically grass veld with scattered trees, and the soil type is a very deep red or red-brown loam without profile, except that the top six inches have some humus, although the humus layer *per se*, is very thin or absent.

Topographically, many of the plantations are situated on slopes of hills; there is frequently a much higher rainfall there compared with the veld below and above.

INTRODUCTION OF EXOTICS, USE OF ARBORETA, AND CHOICE OF SPECIES.

It is only in recent years that the regeneration of the indigenous species has been studied, but it appears that few if any of these are suitable for afforestation purposes, because it is stated that it is difficult to establish them on land other than existing forest soil, while their rate of growth certainly is very much slower than that of many exotics. The maintenance of the existing forests as such will ensure that the indigenous tree flora will not disappear, but it would be interesting in addition to see a number of the indigenous species tried out experimentally in plantations, pure and mixed. For example, *Podocarpus* produces a superior type of softwood timber, and in the old Slave Market Building in Cape Town beams and doors of this timber over two hundred years old are still in good preservation.

The history of the introduction of exotic trees into South Africa is quite an old one, because Van der Stel, the well known Dutch Governor, planted groves and avenues of oak in and near Cape Town more than two hundred years ago, while *Pinus pinaster* is believed to have been introduced by the Huguenots at least prior to 1800.

In the search for the best exotic tree species for the many and diverse conditions in South Africa, two sound principles have been followed and developed consistently and thoroughly. From the time of Sir David Hutchins, exotics have been tried from regions with similar climatic conditions to those for which they are required in South Africa, and this matching of conditions is now done in great detail, and with perhaps too little faith in the adaptability of species to a certain range in conditions of environment. Secondly, before any extensive use of a species is made, it is tried out in arboreta both in groups and in plots. One of the first of these arboreta was begun in 1884 at Tokai near Cape Town. This has proved an unusually favourable site, and some species, for example, *Pinus insignis*, have proved less tolerant of soil conditions than appeared likely from the earlier trials, but this has been adjusted as experience was available from more extensive trials elsewhere. Similarly, in the subtropical, summer rainfall regions in the northern Transvaal, there are arboreta at Woodbush, Entabini and elsewhere which have provided data as to the most suitable species for the conditions there.

The silvicultural variations of growth and crown form which *Pinus pinaster* has shown in South Africa, has indicated the importance of not only selecting the best species, but also the best train of a species, and this is being energetically followed up.

To begin with, persistent efforts were made to find suitable mixtures rather than to rely on pure stands, but in general this has proved unsuccessful up to the present.

The maintenance of soil fertility both in pure pine and pure eucalyptus

stands presents an important problem both in the south, where the soils exhibit podsolic tendencies, and in the subtropical zone, where an increase in humus content may be expected to give important physical improvements, from the analogy of experience in citrus cultivation in the same region. If suitable leguminous species could be found to provide an understory, then the humus conditions would be improved and the nitrogen supply increased.

In the warm temperate conditions in the south with winter and all the year rainfall, *Pinus pinaster* has proved the most tolerant species, growing well on all soils. It is now being restricted to the poorer acid soils, and the better soils used for more productive species. In the George and Knysna region it is estimated that 65 per cent. of the area is under *Pinus pinaster*. *Pinus insignis* is the next most important species. It requires moderately good soil conditions, and checks in growth on wet, acid, peaty soils, recovering only gradually. *Pinus canariensis* has been used more recently on an extensive scale and shows considerable promise on the better soils. *Pinus palustris*, *P. caribaea*, *P. echinata*, and *P. taeda* from the south-east of North America, *P. muricata* from California, and *P. halepensis* from the Mediterranean are also being used on a small plantation scale. To begin with *Eucalyptus* species were favoured, but the growing realization of the importance of softwood production, the disastrous defoliation of *E. globulus* by the Australian Snoutbeetle, *Gonipterus scutelatus*, and the better growth of *Eucalyptus* spp. under subtropical conditions, have led to their restriction in the south to fire lines. For this purpose *E. diversicolor* is used principally, and others such as *E. sieberiana*, are being tried. In valleys on deep soils, the valuable furniture wood *Acacia melanoxylon* is used to a certain extent and grows well.

For subtropical conditions in the north and east, less lengthy experience is available, and further data may lead to modifications. Up to the present *Pinus patula*, a Mexican species, has been the principal tree used for afforestation, taking the place of *P. pinaster* in the south. It is probably the best species for the cooler and higher sites. *P. longifolia* from the Himalaya has proved a good tree on the hotter and drier slopes, for example those with northern aspects. *P. caribaea* is a promising species and is tolerant to a wider range of conditions than *P. patula*, doing well at lower elevations in the Zoutpansberg mountains, at the coast in Zululand, and even on the acid soils at Knysna as already mentioned. *P. taeda* is also used and like *P. caribaea* is fairly tolerant to acid soils. A number of Mexican pines in addition to *P. patula* have been tried out in arboreta and *P. Montezume*, *P. leiophylla*, *P. pseudostrobus* and *P. teocote* appear likely species. *Cryptomaria japonica* has been planted on a fair scale, but has proved exacting as to soil conditions, while the cost of weeding on the grass veld is high because of its relatively slow growth in early life. *Cupressus lusitanica* is also exacting in its soil requirements, but grows well on the deep red soils. *Eucalyptus* spp. are now used only on a relatively small scale. *E. paniculata* is favoured for the poorer soils and hotter slopes, while for the best sites *E. microcorys* and *E. saligna* are best. The last-named species is extensively used by private planters, for the production of mine props on the

coppice system for which it is admirably suited, a five-year rotation giving, under favourable conditions, 50 tons per acre of props suitable for the Rand mines. Other general utility species are *E. maculata* and *E. pilularis*. *Cedrella odorata* and *C. tuna* will probably be used for the best conditions. In the past *Grevillea robusta*, the Australian Silky Oak, was used for fire lines but its leaf debris is inflammable, and *Syncarpia laurifolia* is now preferred for this purpose.

It can be seen, therefore, that while the importance of large-scale production of individual species or types of species is realized, risks are being spread by the use of a reasonable number of species.

LABOUR AND SETTLEMENT.

There is in general an abundant labour supply available at all forest centres, although the type of labour varies in different districts. In the George and Knysna districts, there is a large number of the so-called 'Poor Whites', who present a problem which has certain points of similarity to the unemployment problem at home. It is the policy of the Government to employ poor whites on forestry work in these districts, and cottages have been built forming small villages within the forests. Different types of cottage have been erected. One type is built largely of local materials, the walls being sods cut from the veld and roofed with local thatch. A three-roomed cottage with rooms 12 feet by 9 feet costs £80. A more modern type built of corrugated iron, and with rooms 12 feet by 12 feet, costs £120 to £150. A garden is provided but typically there is no small holding. Each settlement or village has a school, a nurse is resident in the village, and arrangements are made for the weekly visit of a doctor, the settlements generally being a considerable distance from towns. The cost of these services falls on the forest department with the result that, together with the increased cost of the labour, the cost of forest establishment is doubled. The forest worker normally works 5 days a week in the forest, the current rate of pay being 6*s*. 4*d*. per day.

In the Cape region the coloured people provide the labour needed. The rate of pay is 3*s*. to 3*s*. 6*d*. per day, and they live in their own villages.

Further north the forest labourers are recruited from the different tribes of the native Bantus, and the average rate of pay is 1*s*. 9*d*. per day inclusive of their food allowance.

METHODS OF ESTABLISHMENT.

The foundation of the methods of afforestation in South Africa is an unusually thorough cultivation of the land before sowing or planting. After the land has been cleared of scattered trees and larger vegetation, when any are present, it is ploughed whenever the topography permits, usually with six pairs oxen, although mules are sometimes used; this is followed by harrowing. The land is then left about twelve months when the ploughing and harrowing is repeated, generally crosswise. When the ground is too steep or rocky for ploughing the land is picked up either *in toto* or in strips or patches. The total cost of this treatment varies with conditions, but it usually lies between £1 10*s*.

and £3 per acre. In this way the natural vegetation, whether it be the heath or grass type, is completely destroyed, and the young trees are freed from competition, particularly for water, until reinvasion takes place. The heath vegetation generally takes 2 or 3 years to come back, but the grass invades more quickly.

The method of establishment varies to some extent with species. *Pinus pinaster* is almost always established by direct sowing, seed being plentiful and cheap, namely about 1*s*. per pound. The general consensus of opinion is that broadcast, rather than spot or line sowing, is best for this species. To begin with, large quantities of seed were used, up to 100 lbs. per acre, but successful results are obtained with 8–10 lbs. which is the amount now used. *Pinus canariensis* is also sometimes established by direct sowing, generally in spots 5 or 6 seeds per patch, but all other species are almost invariably planted.

The method of nursery practice followed in South Africa is generally known. Petrol tins are cut in two and holes punched in the bottom. A soil-humus mixture is used, the latter brought from the plantations. The seed is sown, and after 3 to 6 months the seedlings are pricked out into tins, 25 to a tin. The stock is planted out when 9 to 12 months old (Eucalyptus 6 to 9 months) when the average size is about 6 inches. Watering is usually necessary, and the seedlings are shaded for a few days after pricking out. The plants are normally taken in the tins to the planting sites, but recently in some forests they are transported with naked roots. The labour, seed and material cost is, on the average, about 30*s*. to 35*s*. per 1,000 plants.

This method of raising plants has certain advantages over the more orthodox method. The principal of these is that it tends to form that type of root system which makes it easy to move plants without loss. Examination showed that even *Pinus pinaster* which normally has a long tap root with few lateral roots, had developed under this system a relatively compact root system. This appeared to be due partly to the confined space in which the plants were grown, partly to early transplanting, and partly to profuse development of mycorrhiza. The practice of mixing humus from plantations ensures heavy inoculation of the soil in the tins with mycorrhiza, and it is possible that the well aerated conditions in the tins, favour mycorrhizal development. Where exotic species, particularly pines, are being used for afforestation on land where trees have never been grown before, this method of nursery practice with initial inoculation of the soil in the tins with humus containing mycorrhiza provides a simple and effective means of ensuring the development of mycorrhizal roots. Further, the intensive cultivation of the plantation sites ensures their continued development. The form of the root system developed by the pines in the tins is of course abnormal for the species, and if it persisted after planting would decrease their resistance to drought. There was, however, no evidence in the aerial development of the plantations that this was so, and it is probable that the plasticity which enabled the compactness of the root system to be developed ensured the rapid reversal to the normal deeper rooting habit after planting.

The espacement adopted for pines and eucalyptus has varied from time to time, but at present pines are normally spaced from 5 feet by 5 feet to 6 feet by 6 feet, while for eucalyptus the espacement varies from 6 feet to 8 feet.

The thorough cultivation before planting makes subsequent weeding unnecessary or light on the heath types in the temperate zone, but on the grass veld in the subtropical region, hoeing and weeding is necessary until the plants get away, especially where complete ploughing is not possible.

The cost of establishment varies partly with the site conditions, but depends principally on the type of labour employed. At George and Knysna with poor white labour, and the heavy incidental charges referred to above, the cost is about £17 10*s*. per acre; in the Cape region with coloured labour it is £5 to £7 per acre; while in the northern Transvaal with native labour, but with charges for clearing scattered trees, and with heavier cultivation and weeding costs, it is about £8 per acre. These costs include everything except overhead charges, and they may be considered low for the intensive methods used and the excellent results secured.

GROWTH AND YIELD.

The most striking feature of the growth of exotic trees in South Africa is its phenomenal rapidity at least up to 30 or 40 years, there being few older plantations of any species. Plantations, which according to European standards one would expect to be 30 or 40 years old or more, are actually only 10 to 20 years. The slowest growing species is *Pinus pinaster*, which does not start off spectacularly. At 10 years it is usually 15 feet high, but by 20 years 40 feet or more is the usual height. An interesting feature of stands even 20 years old is the abundant natural regeneration which often springs up under the dense canopy conditions. This indicates that natural regeneration should be secured by the simplest methods. The growth of *Pinus insignis* is much more rapid, a height of 5 to 6 feet being common only 2 years after planting. At 10 years 40 to 50 feet may be expected, while a stand at Tokai was seen with a height of 90 to 100 feet at 20 years, although this height is not obtained on the average until 30 to 40 years. A novel characteristic of the growth of *P. insignis* is that frequently growth in the main shoot may be made for several years without the production of any side branches so that a long pole, 20 feet or more, is produced. This species also regenerates freely, and there is a considerable area at Tokai naturally regenerated from adjoining plantations after fire. The height growth of *P. canariensis* is intermediate between the above two species, and the other pines used in the temperate zone are similar in growth to the latter.

Experience for the coniferous species being used in the subtropical zone is not so long standing, but *Pinus patula* is growing as fast, if not faster than *P. insignis* in the temperate region, while the other pines being used also show vigorous height growth. *Crytomaria japonica* has attained 30 to 40 feet in 10 years.

The growth of the best eucalypts is of course phenomenally fast. *E. saligna*,

the fastest growing species, usually attains in the subtropical zone 6 to 10 feet in the first year after planting, 50 to 70 feet at 5 years, and 80 to 100 feet in 10 years. Several other species such as *E. microcorys*, *E. paniculata*, and *E. maculata* attain the latter height in 12 to 15 years.

The rotation on which the pines will produce saw timber, and the mean annual increment which will be produced on that rotation, are as yet problematical. It appears, however, that a rotation of 40 to 60 years will be ample, and yields of 200 to 250 cubic feet per acre per annum may be expected for *P. pinaster*, and 300 to 400 cubic feet per annum for the faster growing species, in each case including thinning yields. The yield to be expected from eucalypts, especially in the subtropical zone for which they are best suited, is still doubtful because stands more than 20 years old are rare. The yields up to that age have varied from 150 to 400 cubic feet per acre.

TENDING.

Experience regarding the thinning and other tending requirements of the different trees used for afforestation, is not of long standing even for those used earliest, but the necessity of early and heavy thinnings for species which show such rapid growth, particularly under conditions where moisture is a limiting factor, is fully realized. Thinning as heavy as growth response permits is also desirable for another reason. As existing local supplies of softwood are so low, it is necessary to produce sawmill sizes at the earliest possible date. *Pinus pinaster*, being generally broadcast sown, requires early thinning generally from the fifth to seventh year, when a height of only 6 to 9 feet has been attained. Thereafter, moderate to heavy low thinning is required every three to five years. The slower height of this species combined with strong branch development, particularly in certain races of it, will necessitate relatively lighter thinnings than most other pines, unless it is subsequently managed for the production of resin. The other pine species, particularly the very fast growing ones such as *P. insignis* and *P. patula*, require thinning at 7 to 10 years even at an espacement of 6 by 6 feet. It appears certain that these species require as heavy low thinnings, that is a C grade, as it is possible to make without causing permanent breaks in the canopy in order to give adequate and healthy crowns, and well-developed stems.

Initial espacements of 6 feet or more, followed by heavy thinnings will of course produce wide ringed timber. Provided, however, that the thinnings are repeated at regular intervals, the rings will be even in size, which is the principal requirement. Further, clean timber will not be produced without pruning, and this is being put into practice. The present intention is to prune all the trees up to about 6 feet at the time of the first thinning, followed later by pruning up to 20 or 25 feet of trees which will likely form the final crop. The problem of the maintenance and improvement of soil fertility under these conditions is one which has not yet been considered. No excessive formation of raw pine humus was seen, and with heavy thinning this should be obviated. On the heath types, however, the invasion of the natural vegetation which

tends to form an acid humus, will accentuate the development of podsols with impoverished upper horizons, which appeared to be the natural soil development, at least under certain conditions. In the subtropical zone, the re-establishment of grass under the stands will make heavy demands on the soil moisture. It appears therefore that a search should be made for species which will form an understory, produce a good humus, and if possible fix nitrogen. All possible leguminous species might therefore be considered.

The tending of eucalypts raises a number of difficult but interesting problems. In state plantations the aim will probably be to grow large-size timber for sleeper production, utilizing the earlier intermediate yields for mining props. The phenomenal height growth, combined with the light demanding qualities of most species, makes heavy thinning a necessity if adequate crown development is to be maintained. If opened up too much, however, several species tend to 'feather', that is to produce epicormic branches. It is not clear how far this is detrimental to the timber. Further, all eucalypts make great demands on soil moisture. Thinning therefore is necessary to provide sufficient water to ensure full development of the remaining trees. Most species, however, coppice freely, so that competition for water continues after the thinning is made. For these reasons mixture with other species is being tried. *Grevillea robusta* has been used, but it is not sufficiently shade-bearing to persist long enough, and *Syncarpia laurifolia* is now favoured. A solution may be found by spacing the eucalypts at 18 to 20 feet, filling in with *Syncarpia* to make the usual espacement.

RESEARCH.

The principal problem which has faced the Forest Department up to now is the selection of trees best suited for the economic requirements and different conditions in the Union. The solving of this problem has necessitated detailed study of species and habitat conditions in many different parts of the world, in some instances personally by officers of the departments, the obtaining of seed supplies, the formation of arboreta, and the keeping of records regarding growth and development. This work has been done in considerable detail, and masses of data have been accumulated. It is not yet completed as the recent necessity of studying different racial characteristics of *P. pinaster* indicates, but as the best trees for different conditions and needs are sorted out, it will gradually diminish.

One striking feature of the afforestation work in South Africa is the small place which difficulties in the establishment of tree crops has occupied. This appears due to the very suitable land which has been secured for afforestation, and to the thoroughness of the cultivation methods employed. An example of such a problem, however, was seen in the checking of *Pinus insignis* after planting on wet acid conditions on certain limited areas in the George and Knysna districts. This appeared to be inherently a problem of aeration, and drainage may be expected to reduce the period of check.

In the same district certain pines show poor colour and growth on a red

brown soil which covers limited areas, the cause of this check being unknown. On the whole, however, admirable vigorous young plantations have been secured on a variety of conditions, and on a large scale.

The formation of large areas of different exotics has, and will, present problems of thinning, pruning, &c. Sets of thinning plots have been laid out in plantations of different species, but one of the most urgent problems appears to be the extension and systematic development of this work on the most modern lines.

One still uncertain factor is the quality of the timber which will be produced by the different species which are being employed. On the whole it is surprising that such fast growing species should produce such good timber, and there appears every prospect that if the timber is grown with even rings, although not necessarily narrow, free from knots, and in suitable sizes, that a considerable part at least of the Union's timber needs, now imported, can be competitively grown. The small amounts of the timber of different exotic species already available have been readily marketed at prices, which, with the cost of formation incurred and production which may be expected, should be on the whole remunerative to the State. Much work will have to be done in finding the best uses and treatments for the different species now grown, and the department has recently built a new timber testing station, and the staff is energetically tackling the many and difficult outstanding problems.

In addition to the research work which the afforestation programme necessitates, the department is co-operating with the private growers of wattle, by providing a research officer to study the possible improvement of tannin yields by silvicultural and other methods. There is also the important question of the regeneration and improvement of the indigenous forests, and this research work is located at Deepwalls, Knysna. A considerable amount of ecological data has been accumulated, and the next step is the silvicultural application of it.

This article has been written after a visit to afforestation centres in the Western, Midland, and Transvaal Conservancies, while visiting South Africa for the British Association 1929 Meeting. Very special acknowledgements are made to the Chief Conservator, Mr. C. E. Legat, and Mr. C. C. Robertson, Professional Assistant, who arranged for these visits and accompanied the foresters attending this meeting, and to them and to the Conservators and other officers in these conservancies and to the research officers for their many kindnesses and help, and for most of the information on which this article is based.

A REPORT ON THE PROCEEDINGS OF THE SEVENTH INTERNATIONAL CONGRESS OF FOREST RESEARCH STATIONS, HELD AT STOCKHOLM, JULY 1929

BY W. H. GUILLEBAUD

THE last Congress prior to the one under report was held in Brussels in 1910 when it was arranged for the next Congress to be held in Hungary in 1914 under the Presidency of Dr. Vadas; the Great War, however, intervened and hence the gap of 15 years before the Congress was resummoned to Sweden under the aegis of Professor Hesselmann.

The inaugural session of the Seventh Congress took place on the 22nd of July in the splendid building of the High School of Forestry in the north-west of Stockholm. The Congress was addressed by the Prime Minister of Sweden, Herr Lindman and by the President, Professor Hesselmann, who discussed the reorganization of the International Union of Forest Research Stations. Herr Sven Petrini outlined the proposals of the Swedish organizing committee concerning the Congress, and an organizing committee was appointed consisting of one delegate from each country represented at the Congress. The committee comprised 27 members, of whom the following represented the British Empire:

Great Britain	R. L. Robinson
India	C. G. Trevor
Australia	S. Garthside
Egypt	Shawki Bakir.

The proceedings terminated in the morning with an address by L. von Post of Sweden on the historical development of the Central European forests in the light of recent pollen investigations.

In the afternoon another full session was held at which several papers were read including one by Professor Flury of Switzerland on the position regarding the creation of an international forest bibliography, and another by Professor Oppermann of Denmark on some future tasks for the International Union of Forest Research Stations.

Professor Flury described the inception of the idea of an international forest bibliography which dated back to the fourth meeting of the International Union held at Vienna in 1903 when a Bibliographical Commission was appointed to consider the matter. Various meetings were held, the last in Zurich in 1926 when a classification on the basis of the bibliographical decimal system of Melvil Dewey was recommended for adoption. Professor Flury urged the importance of coming to a decision on this matter so that work could be started without further delay.

Professor Oppermann outlined a series of tasks which he considered should

be undertaken by the International Union. Among these were the following:

1. The collection and distribution to Research Stations of details regarding maximum production yielded by the various species in the different countries.
2. Forest Topography, i. e. a topographical description of the principal forest areas in each country.
3. An annual report on the activities and personnel of Research Stations.
4. Forest Vocabularies defining the technical forestry terms in general use.
5. Forest Guides, i. e. descriptions of interesting and important forests.
6. An introduction to the forest literature of each country.
7. International Forest History.
8. Library of the classic works on forestry.

After the full session of the first day the Congress divided into four sections dealing respectively with General Forestry, Forest Ecology, Soil Science, and Forest Entomology. There were 97 papers for discussion, the majority of which were read, and a wide range of subjects was covered in each section.

Space does not permit of reference to the papers in detail, but an attempt to summarize their general trend may be of interest. In the General Forestry Section several of the papers dealt with the progress of silvicultural research in the respective countries, but perhaps the subject most thoroughly covered was that of forest mensuration and, in particular, the technique of sample plot work. Many of the papers described refinements leading to greater accuracy in detailed measurements, and the general difficulties and complexities of the work were fully recognized. Professor Wiedemann outlined the major conclusions to be drawn from the recent working up of the data from the Prussian sample plots laid down many years ago by Schwappach. He also stated that within the past year 100 new plots had been established by him, of which the majority were laid down with the object of studying comparative thinning methods. In each set of plots the principle of replication was adopted, the number of parallel plots ranging from three to five. This principle of replication was also strongly advocated by Dr. M. L. Anderson in his paper on sample plot technique with reference to British conditions. Another interesting paper was that read by Ilvessalo on the forest type method used in Finland for the classification of site localities.

The Ecological Section dealt with such diverse subjects as the introduction of exotic species, races and types of trees, root competition, natural regeneration, seed supply, forest fires and fungal diseases.

Many interesting and important papers were read in the section for Soil Science, including papers dealing with soil types, humus, soil micro-organisms and the afforestation of waste land, read by such authorities as Dr. Tamm, Professor Hesselmann and Dr. Melin of Sweden, Professor Weiss and Dr. Bornebusch of Denmark, and Dr. Waksman of the U.S.A.

In the entomological section Professor Trägårdh of Sweden read papers on

the methods of investigating the fauna of dying trees and on the determination of the loss of the assimilating organs of trees in consequence of attack by leaf- and needle-eating insects. The control of pests by arsenic preparations was also discussed.

A number of statements and resolutions were passed by the various sections and remitted to the International Committee of the Congress for consideration.

The final general session of the Congress was held on Saturday, July 27, when the Statutes adopted during the course of the Congress by the International Committee were read. The next Congress was arranged to be held in France in 1932 under the Presidency of M. Guinier and the succeeding Congress in Hungary under the Presidency of Herr von Roth.

A permanent Committee consisting of the following members was appointed to consider the question of Forest Bibliography:

M. Flury	Switzerland.
M. Perrin	France.
Professor Oppermann . .	Denmark.
Professor Troup . . .	Great Britain.
Professor Weber . . .	Germany.
Professor Hesselink . .	Holland.

A General Permanent Committee was also appointed and it was decided by the International Committee to refer the resolutions passed by the Sections to that Committee.

The proceedings terminated by the exhibition of a film showing forestry work in Japan.

The following is the text of the revised statutes adopted by the International Committee, and of the resolutions submitted by the Sections.

TEXT OF THE REVISED STATUTES

1. The name of the association is 'The International Union of Forest Research Organizations'.

2. The aim of the Union is to promote international co-operation in the various branches of forest research. It exercises its activity especially:

(i) by summoning regular meetings or congresses, combined or not with excursions for the purpose of studying forestry,

(ii) by working, as far as possible and expedient, for the introduction of uniform nomenclature and standardization of methods in forest research work,

(iii) by providing for the establishment of an international forestry Bibliography.

3. Two classes of membership are recognized (*a*) Ordinary Members, and (*b*) Associate Members.

(*a*) Ordinary members shall be of two classes.

(i) State-established Forest Research Organizations. These become members of the Union merely by giving notice to the President of the Union of their intention to join.

(ii) Organizations carrying on the same kind of work as State-established Forest Research Organizations and founded by Universities or other corporations. These may be elected ordinary members upon the nomination of the representative of their country (Article 6, paragraph 2) and on the proposal of the Permanent Committee by a resolution passed by the International Committee.

(*b*) Associate members shall be those private individuals engaged in forest research. They may be elected by the Permanent Committee upon the nomination of the representative of this country, subject to the ratification by a two-thirds majority of the International Committee.

4. The organs of the Union are:

(*a*) the Congress,
(*b*) the International Committee,
(*c*) the Permanent Committee,
(*d*) the President,
(*e*) the Secretary General.

5. The congress, which is the general assembly of the Union, discusses scientific forestry questions.

It consists of:

(*a*) the members mentioned in Article 3,
(*b*) any persons engaged in forest research receiving a special invitation.

The Congress meets every three to five years on the initiative of the president.

Every ordinary member of the Union has the right of being represented by as many delegates as it chooses.

6. The International Committee, which is the highest authority for all matters of organization and management (subject to the provisions of Article 10) shall consist of one representative from each country that has any ordinary member in the Union, or from which a request for admission has been addressed to the Union, the countries being differentiated according to the same principles as those applied in the Universal Postal Union. The representative of each country should usually be a person engaged in forest research.

The International Committee shall meet generally only in connexion with a Congress. It can, however, meet in extraordinary session either upon call by the president or at the request of one-third of its members.

It fixes the year of the next Congress and the country in which it is to be held; it elects the President of the Union, the members of the Permanent Committee and those of the Bibliographical Commission.

It examines the report of the Permanent Committee and the accounts of the Union.

It decides finally the action to be taken upon the proposals submitted by the Congress and its sections, as well as the admission of the Associate Members mentioned in Article 3 (*a*) (ii) and 3 (*b*).

It has the right of appointing special commissions on which experts who are not members of the Union may be invited to sit.

Every ordinary member of the Union has the right to bring before the International Committee any individual proposal concerning the work of the Union and to have such proposal presented to the Committee by its representative.

7. The Permanent Committee, which is the executive organ of the Union, shall consist of the President, a Vice-President, and five members; it shall be elected by the

International Committee by a majority vote. Its period of office shall be from the first of January of the year following the close of the congress during which it is elected, to 31st December following the next Congress.

8. The President shall preside over the Congress, over the International Committee, and over the Permanent Committee. He shall be elected by the International Committee at every Congress and must be a national of the country where the next Congress is to be held. His term of office shall be from the 1st January of the year following the close of the Congress during which he is elected, to 31st December following the next Congress.

Should the office of President become vacant before the expiration of his term of office, the Permanent Committee shall elect a new President, who shall be a national of the same country.

9. The Secretary General shall be appointed by the International Committee which shall also fix his salary. He shall be subject to re-election at each Congress.

He is a permanent official of the Union, and shall carry out its decisions.

The Permanent Committee shall supervise his whole activity.

Should the office of the Secretary General become vacant before the expiration of his term of office, the Permanent Committee shall appoint a new Secretary General.

The residence of the Secretary General shall be legally considered as the seat of the Union.

10. Ordinary members shall pay to the Union a minimum annual subscription of 120 Swiss francs.

Any increase in this subscription may only be decided with the consent of the majority of the members concerned.

Associate members pay a minimum annual subscription of 20 Swiss francs.

All subscriptions shall be due on 1st January of each year, and shall be paid to the Secretary General by 31st January; the full annual subscriptions shall be paid for the year of admission.

11. The funds of the Union shall be administered by the Permanent Committee, which shall be liable to render account to the International Committee. The accounts of the Union shall be kept by the Secretary General, who shall also be able to sign cheques and receipts.

12. The decisions of the International Committee shall be taken by a simple majority of the votes cast, provided that they shall be approved by at least one-third of the entire membership of the International Committee.

Any change in the Constitution of the Union, as well as in the application of the provisions contained in Article 3, paragraph *b*, requires a majority of two-thirds of the entire membership of the International Committee.

TEXT OF THE SECTIONAL RESOLUTIONS [1]

I. *International Organization for the Collection of Seed with a Guarantee of Origin. Proposed by M. Guinier, France.*

Two measures are proposed for the consideration of the International Congress of Forest Research Stations:

(i) The organization in each country of the collection and extraction of forest tree seeds of known origin under the supervision or under the strict control of the Forest

[1] The majority of the resolutions were submitted in French or German and have been translated by the writer of this article.

Services. The various Research Stations have an important part to play in the discovery and identification of interesting races and in the indication of the technical means of employing them.

(ii) The organization of a system of international exchange of the seed thus collected. The International Union of Research Stations should establish the basis of this organization and ensure its proper functioning.

II. *Proposal by M. Oudin, France.*

In order to obtain as large a diffusion of knowledge as possible, I beg to request all the Institutes affiliated to the Union to consider the following proposals:

(i) To insert in their publications at the end of each article a short summary in one or more of the following languages: French, German, English.

(ii) To insert in the tables a translation in French, English or German of the heading of each column.

III. *Resolution by M. Sokolowski, Poland.*

In view of the great importance which nature parks and reserves have for forestry research, the International Congress of Forest Research Stations in Stockholm makes the request to the Governments of all the Stations represented at the Congress to give the greatest support possible to the establishment of nature parks and reserves.

IV. *Proposal by M. Vasquez, Spain.*

The International Congress of Forest Research Stations expresses the desire that the Research Stations should be invited to study all types of forests which are of interest from the economic standpoint—that is, even when wood is not the most remunerative product—and that in particular, investigations should be organized dealing with those forests which produce resin, bark, cork, &c., as well as those which are utilized for grazing.

V. *Statement and Proposal by M. Perrin, France.*

M. Perrin emphasized the increasing interest which attaches to the determination of the quality of timber, both in relation to the rational utilization of timber and in the orientation to be given to the treatment of the forests with a view to obtaining timber of known properties. M. Perrin made the proposal that certain Research Stations should take up the study of this question with a concerted programme of work and investigation designed to provide those in charge of forests and those who make use of the timber with all the necessary information.

VI. *Proposal by Mr. Robinson, Great Britain.*

That the question of establishing replicated plots in the study of different methods of treatment (for example, in thinning) should receive the careful consideration of the Congress, and that adherents thereto should investigate the subject experimentally and report the results to the next meeting of the Congress.

VII. *Proposal by Mr. Munns, U.S.A.*

It is recommended that a committee of seven members, representing as many nations, be appointed to bring together and correlate as far as possible, the best practices employed by the various countries in the establishment and measurement of sample plots, and the measurement of standing and felled trees.

VIII. *Resolution by Professor Konsel, Czechoslovakia.*

The International Committee are requested to appoint a sub-committee to draw up a standard list of mathematical symbols for use in forest mathematics by all research stations who are members of the Union.

IX. *Proposals by M. Kalnins, Lithuania.*

(i) In order to obtain internationally comparable data as to the chemical composition of the different woods, it is most necessary to lay down standard methods of determination, just as has long been done in the case of the mechanical properties of woods.

(ii) It is desirable that the forest research stations should devote more attention to the chemical strength of woods. It is possible by such investigations to solve many problems of forestry.

X. *Resolution by M. Grochowski, Poland.*

The International Congress is asked to agree that the problem of the influence of thinnings on the development and increment of trees and stands can best be solved by the establishment of two kinds of sample plots on the principles laid down by the author in his paper read to the General Forestry Section of the Congress.

XI. *Resolutions passed by the Section of Forest Ecology.*

(i) The International Union of Forest Research Stations should request the component Research Stations to undertake as far as may be possible the collection of forest seeds of different origin and from stands of good type with an exact specification of the origin in terms of latitude, longitude, elevation, and other ecological factors.

The Forest Research Stations should notify the General Secretary as soon as possible of any surplus to the requirements of their own country in order to facilitate distribution.

(ii) The Section of Forest Ecology attaches great importance to the preparation of a standardized form of locality description and considers that the International Committee of the Congress should appoint a sub-committee whose duty it shall be to prepare such a standardized form of description for submission to the next International Congress of Forest Research Stations. The permanent Commission in Prague of the Union of Forest and Agricultural Research Stations of Czechoslovakia was entrusted with the task of making the necessary preliminary enquiries.

XII. *Statement and Resolution by Professor Konsel, Czechoslovakia.*

Now that forest research has reached the stage of the formation of an international union it must proceed to systematize methods of research, and also, as far as possible, deal with the allocation of problems. While many problems are of a purely local nature, a great number of silvicultural problems require investigation on the widest possible territorial basis but with comparability as a prerequisite. The development of uniform methods of working appears to me to be one of the first conditions for the success of international forest research. I ask the members of the Ecological Section to adopt the following resolution:

The proposal is made that guiding lines should be drawn up by the Congress in order to enable investigations which are conducted internationally to be properly comparable.

XIII. *Proposals by Professor Konsel, Czechoslovakia.*

(i) An international committee should be appointed to lay down the requirements necessary in respect of guarantees as to the origin of seed in each region.

(ii) A committee should be formed to investigate stands of the same species in different countries and to assess the value of regional varieties.

(iii) The collection of forest tree seeds should be allowed only under the control of duly appointed experts who will be authorized to certify as to time of collection, locality, quantity of seed collected, and identity of vendor.

(iv) The trade in forest tree seeds should be placed under international control, and statistics duly published.

XIV. *Proposal by Professor Fabricius, Germany.*

In making locality descriptions the previous history of the stand should be recorded as that has a great influence on both trees and soil. General climatic data are also often of value, but the distance of the locality in question from the climate recording station should be mentioned and it should also be stated to what extent the data given can be regarded as applicable to the locality in question. In especial, mention should be made of local frost danger and the prevalence of thunderstorms.

XV. *Proposal by Dr. Nemec, Czechoslovakia.*

There are comparatively large areas of Scots pine forests in the Quader sandstone regions of Bohemia which, in consequence of prolonged stocking with pure Scots pine combined with the clear felling system, have a soil which has greatly deteriorated. The evidence for the deterioration is the podsolization of the soil with the presence of impermeable pan layers. On such soils plantations of Scots pine and other species are not able to thrive permanently. The growth of the existing pine stands is so poor that in many places the trees at fifty years of age are not more than 12 to 15 ft. high. So far the ordinary silvicultural methods, which have been applied have proved a complete failure. The future is thus most discouraging as these areas can no longer be replanted successfully, using ordinary methods of cultivation.

The author proposes that a special commission should be appointed by the International Union in order to find the scientific and practical solution of these important problems.

The following questions should be investigated in particular.

(i) The results which can be obtained by breaking up the pan layers by ploughing and mixing together the upper strongly podsolized layers of the soil, lime also being applied.

(ii) The influence of cropping the land so improved with agricultural plants (potatoes, oats, rye, or *leguminosae*).

(iii) The effect of underplanting hardwoods on soils which have not been broken up mechanically.

(iv) The most suitable types of mixed stands to establish on soils treated under (i) and (ii) above.

XVI. *Proposal by Dr. Bornebusch, Denmark.*

The Congress shall appoint a Committee of three to five persons to discuss the nomenclature of the humus forms in the forest and submit proposals to the next Congress.

XVII. *Decisions of the Section for Forest Entomology.*

(i) An international association of Ipidologists will be formed and an announcement to that effect will be made in all the more important world journals.

A Committee is entrusted with the preparatory work of the association and will consist of the following members: Spessivtseff and Trägårdh, Sweden, and Kemner and von Butovitsch, Germany.

(ii) It was decided to postpone the reorganization of the international service of reviews until 1932 when the International Entomological Congress will meet in Paris. Preparatory work in this connexion was left to a committee consisting of Trägårdh and Spessivtseff, Sweden and Kemner and von Butovitsch, Germany.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION MEETING, SOUTH AFRICA, 1929

ON the occasion of the British Association Meeting in South Africa, in July and August 1929, a department of Forestry in the Botany Section was organized as usual. The chairman of this department, was Mr. C. E. Legat, the Chief Conservator of Forests in the Union of South Africa, and the Local Secretary, Mr. C. C. Robertson, Professional Assistant and Chief Research Officer in the Union Department, while Dr. J. D. Sutherland and later Dr. H. M. Steven was secretary of the sub-section. Successful meetings were held in Cape Town and Johannesburg and the range of papers read by South African foresters and others shows the development and importance of forestry in South Africa. The following is a list of the titles and authors of the papers delivered:

The Silviculture of Exotic Conifers in South Africa. C. E. Legat.

Geographical Distribution of Trees as a Guide to their Cultivation. Professor A. W. Borthwick.

Notes on the Exotic Trees in the Cape Peninsula. Mr. G. A. Zahn and Mr. E. J. Neethling.

A Summary of the Working Plan for Tokai Plantation. Mr. G. A. Zahn and Mr. C. H. Clayton.

The Movement of Water and Solutes in the Tree. Professor J. H. Priestley.

The Biology of the Soil and its Relation to Tree Growth. Dr. E. V. Laing.

Environment and Disease: A Discussion on the Parasitism of *Armillaria mellea* Vahl. Fr. W. R. Day.

The Cluster Pine (*Pinus pinaster*). Mr. G. A. Zahn and Mr. E. J. Neethling.

The Canadian Forest Industries. Mr. T. A. McElhanney and Mr. R. D. Craig.

Moisture versus Light as the Limiting Factor in Forest Development. Dr. I. J. Craib.

The Growth of Eucalypts in the Sub-tropical Plantations of the Transvaal and Zululand. Mr. J. J. Kotze and Mr. C. S. Hubbard.

Silvicultural Investigations into Wattle Cultivation. Mr. A. J. O'Connor and Dr. I. J. Craib.

Notes on Exotic Coniferous Timbers Grown in South Africa. Mr. M. N. Scott.

Mining Timber in the Witwatersrand. Mr. H. A. Reid.

The Distribution of the Forest Flora of Nyasaland. Dr. J. Burtt Davy.

Laboratory Studies in Pulping some South African Woods. Mr. E. F. English.

Timbers suitable for Match-Making, by Mr. G. A. Wilmot.

Moisture Content of Wood. Mr. N. B. Eckbo.

The Influence of Man on Forest Environment in Northern Nyasaland. Mr. Paul Topham.

In addition to the Meetings, the Union Forest Department kindly arranged for visits to forest areas in the Western, Midland, and Transvaal conservancies. A number of botanists joined in these excursions, and the contact with specialists in different subjects bearing on forestry, which an overseas meeting facilitates, was one of the most useful features of the whole tour. Later some members visited Kenya where the forest department also kindly provided facilities to see the forests.

REVIEWS

The Structure and Life of Forest Trees. Büsgen. Third, revised and enlarged edition. Münch. English Translation. Thomson. Chapman & Hall, London, 1929. Pp. xi+436. 173 illustrations. Price 30*s*.

Review by R. N. Aldrich-Blake.

ENGLISH-SPEAKING foresters and botanists will be heartily grateful to Mr. Thomson for his lucid translation of the latest edition of Büsgen's *Bau and Leben unserer Waldbäume*, which appeared in 1926. The price of the translation is high compared with 21*s*. for the German edition, but the former is a much finer book, especially as regards the reproduction of the photographs. So far as the translation is concerned we may regret the deliberate omission of further English and American references, on the score of the already extensive bibliography; for the paucity of such references is most noteworthy: but otherwise there can be nothing but praise and thanks for an arduous task well done.

This book keeps the forester abreast of recent advances in plant physiology relevant to his subject. It collects important references for the physiologist from forestry periodicals which may seldom be available to him. It forms a bridge between pure and applied science. The first edition, published in 1897, contained 225 pages, and has doubtless been partly responsible for the enlargement of the present edition, which will in turn be a spur and aid to future research. Students as well as the research workers will welcome the present edition.

The first two chapters give morphological, the next four anatomical data; but a causal physiological outlook runs through this, as through other portions of the book. Teleological explanations are advanced here and there, despite the following sentence on p. 39:

'To determine conditions under which a particular answer follows is the task of the investigator. As to how that power may have come into existence in the past under the influence of the environment is a question which at present does not stand in the scientific orders of the day.'

Though agreeing with this statement we may find that many problems may be seen in broader perspective by imaginative biological speculation. Chapter VII deals briefly with the relations between structure and physical properties of timber. Leaves and roots and their respective functions, the water economy and mineral nutrition of the tree, form the subjects of the four succeeding chapters. The editor's recent theory of the mechanism of descent of the sap stream is advanced in Chapter XII, which deals with movements and transformations of plastic materials. In Chapter XIII some account is given of the reproduction of trees, of the morphology and physiology of flowers and fruits, of seeds and seedlings. The final chapter on tree races, a subject on which Münch has worked extensively, appears for the first time in the third edition.

In criticizing the present edition we feel that it suffers in arrangement by following the order of the first edition, which appeared at a time when knowledge of structure outweighed that of physiology. The book might now be built up round the causal physiological theme, and begin with 'General remarks on the causes of the form of trees (Ch. I, sec. 11), as an introduction to the present final chapter on racial characteristics and their inheritance. Seedling structure and physiology should follow. The general metabolism of the tree should precede a detailed consideration of the influence of

external factors on growth, form, and structure. Besides this general criticism we may accept the section on the time of uptake of mineral substances with caution, for there is no mention of adequate plot technique in the original papers. We may quarrel with the assertion on p. 129 that the tree does not use the inner parts of its wood for the storage of materials, in view of Craib's demonstration that the water content of the centre of the bole of non-resinous trees reaches a high level in winter. But we must admit that the book is a most valuable contribution to our forestal and botanical literature.

The Role of Research in the Development of Forestry in North America, by I. W. Bailey and H. A. Spoehr. Macmillan & Co., New York, 1929. 6*s*.

Review by the Editor

THIS small book of 103 pages may prove to be a landmark in forest research. It presents the carefully thought out views, based on personal visits to most forestry and cognate institutions in America and Europe, of two eminent scientists, Professor Irving Bailey of Harvard University, and Dr. H. A. Spoehr of the Carnegie Institution of Washington. The genesis of the matter is of interest. 'In a paper presented before the National Academy of Sciences in 1924, Colonel W. B. Greeley, then Chief of the United States Forest Service, outlined the gravity of the situation as to present and future national resources in proportion to obvious needs, and asked the counsel of the Academy in meeting the situation.' Following Colonel Greeley's request, the National Academy, appointed a representative group to inquire further into the facts and to report its findings. The publication of this volume presents in some measure the answer of the Academy through its committee to the questions proposed by the Chief of the Forest Service.

The answer in a sentence is the great need of sustained and intensive research into the physiology of trees. As has been stressed on more than one occasion in this journal, we know relatively little regarding the functioning of the units of which our forests are built up, and perhaps still less of the functioning of the forest as a unit. Although the final aim is to discuss how this research can best be carried out, this book will interest all foresters whether or no they are interested directly in research, because it is full of clear thinking on forestry in general, and critical appraisements of forestry teaching as well as research.

In stressing the need for research into basic subjects, the authors do not minimize the importance of the descriptive sciences, such as systematic botany, systematic entomology, physiography, &c., and empirical experimentation, all of which are necessary to the expansion of the systematic management of forests. As far as the United States of America are concerned, however, means are already provided for a great extension of this type of work by the McSweeney-McNary bill, under which new experiment stations will be established, and more money made available. The provision, therefore, of agencies for research into the basic sciences, will crown the organization. The agency recommended after a full consideration of possible courses, is the establishment of special research institutes in University centres and affiliated more or less informally with existing scientific departments.

This book shows that the forest research problems of the United States are being thought out, and means for their solution organized. What of the British Empire? We

have forests of much greater diversity of type, and problems of even greater difficulty, but means for research are scanty, and research and researchers in different parts of the empire loosely linked together, if at all.

British Hardwoods: their Structure and Identification, by L. Chalk and B. J. Rendle. Department of Scientific and Industrial Research and Imperial Forestry Institute; *Forest Products Research Bulletin* No 3. London. H.M. Stationery Office, 1929. Price 5*s*.

Review by S. H. Clarke

ALL who are interested in wood, whether from a purely scientific or commercial viewpoint, will welcome this volume, which should help to satisfy a definite need. In attempting a work of this kind the authors faced serious difficulties: they were called upon to lay new emphasis on old material, to present facts accurately and simply, to standardize such relative and variable features as the size of pores. The brief and simple introduction, which deals with the principal features in the structure of wood, is well done; the end is kept in view, and the uninitiated reader is not in danger of being side-tracked. Such arbitrary terms as have to be used are standardized as far as possible by reference to certain woods, of which illustrations are given. From the *frontispiece* it may be gathered that 'mature' wood should be used where possible, but this should have been noted in the text. Throughout the book the importance of the 'end-surface' or 'transverse surface' is naturally stressed, but a single illustration of quarter- or plain-sawn wood would have been useful for comparison.

Following the introduction are descriptions of the twenty-three most important British hardwoods. These are arranged alphabetically, and facing each is a photo-micrograph of the end-surface of the wood in question. The descriptions are orderly and concise. The illustrations deserve special mention: they are of good quality, show a much larger field, and are arranged more conveniently than is usual. A key to the identification of the woods is given, so that 'they can be identified with no further apparatus than a sharp knife and a simple magnifying glass or hand lens', and, one might add, a little practice. Though very efficient, the key has limitations at present unavoidable; and the authors have pointed out that it is often impossible to distinguish with complete certainty between willow and poplar.

Special attention is given to the chief timbers. To take a single example, the description of common English oak is supplemented by important information. In a section headed 'Other species of British grown oak', particulars are given of Holm oak and Turkey oak. Under 'Imported oak', the chief species of *Quercus* imported from Europe, America, and Japan are noted. 'Other imported timbers known as oak' are then discussed; these being woods from very different families and often with different properties, but all called oaks because they resemble in one or more respects members of the genus *Quercus*. Each type of 'oak' wood is illustrated, and a table is given indicating distinctive features by which they may be recognized.

A select bibliography not only gives the titles of relevant literature, but briefly describes the scope of each book mentioned.

Throughout, the book is orderly and easy to follow, it is attractively and serviceably bound, and at a remarkably low price. Both the authors and the publishers are to be congratulated on the service they have rendered.

Forestry. A Study of its Origin, Application and Significance in the United States, by Arthur B. Rechnagel and Samuel N. Spring. Alfred A. Knopp, New York, 1929.

Review by W. L. Taylor.

THIS book can be given a cordial welcome in any country among whose people the inculcation of a forest conscience is a task still to be brought to fruition. The object of the authors, as they state in their preface, is indicated by their sub-title and the picture they present of a gradual realization of the need for a national forest policy, arising like the fabled phoenix, out of the ashes of the vast primeval forests of the United States of America, is sharply focused and striking. Early settlers found the forest an adversary to be overcome; later timber developed a commercial value not entirely local, and the axe plied with this further incentive has wrought enormous and rapid wastage. At present the annual depletion of standing timber proceeds at the rate of one-fortieth of the estimated total supply. The authors are at pains to make clear the fact that forestry is an industry and trace its growth in the United States from early in the nineteenth century, showing how it came into being, its development, and its objectives. They explain the public policy regarding forests and the essential importance of forestry in social welfare. The timber industry to-day stands first in number of wage-earners in no fewer than eleven States of the Union.

The course of systematic research into forest problems is outlined and a chapter is devoted to public and professional education in forestry. It is stated freely that Americans as a nation are not yet 'forest-minded', but references to the American Forestry Association go to show the valuable influence exercised by a strong body possessed of a national outlook.

The book is suitably illustrated, the appendices and bibliography are helpful, and a clearly compiled index completes a volume that can be read with advantage by all interested in forestry and the awakening of a national forest sense in Great Britain.

Le pin Weymouth en Suisse, by H. Badoux. *Annales de la Station fédérale de Recherches forestières*, Tome xv. 1, 1929, pp. 105–83. Holz, Blattmenge und Zuwachs. 1. Die Weymouthsföhre by Hans Burger, *Mitteilungen der schweizerischen Centralanstalt für das forstliche Versuchswesen*, xv. 2, 1929, pp. 243–92.

Review by the Editor

IN Great Britain to-day, the less important exotic trees do not command much attention. This is natural, because interest is concentrated on the species which have proved most useful, such as Douglas fir, Sitka spruce, and Japanese larch, and on their extensive use by the State and private individuals. Nevertheless, it is well to consider evidence regarding all trees which may be useful in this country, and in the first article quoted above, Professor Badoux states the Swiss experience concerning *Pinus strobus*.

In Central Europe generally, Weymouth pine was once a popular forest tree, and as elsewhere was used in Switzerland to some extent. The most interesting part of the present paper deals with its resistance to *Cronartium ribicola*, more generally known as *Peridermium strobi*, which has not only blighted the future of one of Europe's most promising exotics, but now threatens the tree on its North American habitat. This rust is generally found on Weymouth pine in Switzerland, and has led to very serious loss, but only in certain regions, such as the Canton of Zurich. In many parts of the country,

the disease, although present and generally causing death to the individuals affected, is not sufficiently widespread to menace the stands as a whole.

The favourable locations for Weymouth pine are on the Swiss plateau, where it is fully acclimatized and regenerates naturally. It prefers deep loose soils and is stated to succeed on peaty soils. Single stem and group mixtures with indigenous species are recommended and the importance of adequate thinning stressed. Under such conditions Professor Badoux considers that growth will be good, and damage from *Cronartium* not sufficiently serious to justify the giving up of this species which not only grows well, but produces a high volume of timber of good quality.

So far as Britain is concerned it must be admitted that Weymouth pine, although introduced over two centuries ago, has not been adequately tried out on a plantation scale. There are only a few plantations of small area, and generally about 20 years old. The rust, although almost always present, has not in all cases proved serious so far, although, in some instances at least, the stands are overstocked and not reasonably tended. If the species grows and remains fairly healthy on peaty soil it may be worth while to consider its further use experimentally.

In the second paper quoted, Dr. Hans Burger gives data bearing on the relationship between the quality of the timber, number of needles, and growth of Weymouth pine. There is comparatively little data of this kind, and this paper will be of interest, particularly to wood technologists. Data for other species are promised and comparison will then be possible.

Untersuchungen über die Weisstannenlaus *Dreyfusia nüsslini* C. B. in der Schweiz. O. Schneider Orelli, C. Schaeffer, and R. Wiesmann. *Mitteilungen der schweizerischen Centralanstalt für das forstliche Versuchswesen*, Bd. xv, Heft 2, 1929, pp. 191–242.

Review by R. N. Chrystal

THIS paper on the biology, morphology and forest relations of the silver fir chermes, *D. nüsslini and D. piceae*, contains the results of the first thorough study of these insects which has ever been made in Switzerland. Both species, as a glance at the literature will show, have been closely studied in several European countries at different times, during the past 50 years, but it is only quite recently that their appearance, especially that of *D. nüsslini*, in the silver fir forests of the Swiss plateau has given rise to some anxiety on the part of the Swiss foresters, and occasioned the studies which are described in the paper.

In presenting the results of their work, the authors have spared no pains, either in the scope of their work, or in the manner of its arrangement, to ensure that all aspects of the problem shall be adequately discussed. The morphological studies which have been very thoroughly done, confirm the main conclusions reached by Marchal in 1907 concerning the morphological differences between the various types of larvae and adults of the sistens, progrediens, and sexual forms which occur during the course of the life-cycle. They also establish the fact that the distinction drawn by Börner in 1908 between *D. nüsslini* and *D. piceae* has been founded upon morphological grounds which are unassailable.

From the biological studies also, two very interesting facts have emerged. The first of these is that *D. nüsslini* is not necessarily localized in its occurrence to the apical

portion of the tree, but that on trees up to 25 years of age, this insect can occur on all parts of the stem, from base to crown.

On such trees, it is of course, quite impossible to distinguish between the two species by superficial observation, but microscopic examination of the young larvae enables one to separate them without the slightest trouble.

This is interesting and is confirmed by some studies made a few years ago in which young larvae of *D. nüsslini* C.B. when transferred to *A. grandis* produced on the buds of that tree galls of an exactly similar nature to those caused by *D. piceae*. Obviously the two species, albeit morphologically separable, are racial offshoots from a common stock.

In their observations on the forest relations of *D. nüsslini* the authors conclude that the most important condition necessary for the protection of young silver fir from attack is the provision of shade. Young silver fir, growing in the open, suffer in their opinion far more seriously from attack than those grown under the protection of an older crop.

The provision of shade is considered by the authors to be the most important control measure which can be devised. Mechanical methods such as spraying, which has been so much resorted to in Denmark of late years, are, in their opinion, measures which can only be of secondary importance.

The conclusion which the authors have reached on the question of the importance of shade as a protection against chermes attack is of great importance, as observations made some years ago in Denmark indicated that access of light to infested stems seemed to have the effect of diminishing the intensity of attack rather than augmenting it.

In this particular instance the insect in question was *D. piceae*, and it is just possible that as regards their reaction to light, there may be a slight difference between the two species. The point, is, however, of such practical importance that some method is clearly desirable whereby statistical studies can be made from which the incidence of chermes attack in shaded and unshaded areas could be definitely estimated, to the exclusion of all extraneous factors.

Plant Ecology, by John E. Weaver and Frederick E. Clements. Mc.Graw-Hill Publishing Co., Ltd., 6 and 8 Bouverie Street, London. E.C. 4., 1929, 25*s*. net.

Review by the Editor

FORESTERS throughout the world, whether they are endeavouring to regenerate Tropical Rain Forest or establish pure plantations of the latest idea in exotics, are looking to the science of ecology in the hope that by its broad principles, and by the technique which it is elaborating, help will be forthcoming in the solution of forest problems. One therefore opens this book by two of the best known American ecologists with a feeling of expectation. The preface states: This volume is designed to meet the need for a comprehensive text-book of plant ecology, and to furnish a guide to workers in related fields. It is written from the standpoint of development, instrumentation, and experiment. At the beginning of the book there is a short note headed 'To the teacher', which outlines the scope of the practical work carried out in the field by students of ecology at the University of Nebraska, and throughout the text-book there are further suggestions in practical work bearing on the different sections.

The general scope of the volume can best be indicated by the subjects dealt with in the different chapters. They are: vegetation, its origin, development and structure;

methods of studying vegetation; the units of vegetation; plant succession; initial causes of succession; aggregation, migration, and ecesis; competition and invasion; reaction and stabilization; factors of the habitat, the soil; relation of underground plant parts to environment; humidity, wind, and evaporation; temperature; light; plant response as a measure of environment; adaptation to water; relations between plants and animals; plants and plant communities as indicators; climax formations of North America.

The field covered by this book is a very wide one, and considering its size, 520 pages, the many subjects are dealt with in considerable detail.

No two authors, however able or industrious, can be equally competent and well informed in all the many aspects of this large subject and it appears to us that the weakest parts of the book are the sections dealing with soil. Climate is of course the controlling factor in the distribution and development of vegetation, but this very principle has taken on a new significance as a result of the increasing realization of the importance of climate in the development of soil type which we owe in a considerable degree to the Russian School of Soil Science. Vegetation is the expression of climate not only directly, but also through the effect of the latter on soil, and the effect of climate on soil type is in turn conditioned by the vegetation. The subject of soil development is dealt with very cursorily, and the reference to the importance of climate on soil characteristics is a short one from Tansley and Chipp. Further, in dealing with the climax formations of North America no reference is made to the soil types associated with them. Foresters in this country are specially interested in the forest formations of North America, and this additional aspect would have increased the value of this section to us. In dealing with humus, the ecological importance of which is recognized, the important and suggestive work of Hesselman and his collaborators is not mentioned, while in the section on soil acidity Olsen's work, which in many ways is the most important which has been done on the ecological aspect of this subject, passes unnoted. A subject of special importance to foresters, namely, land classification receives little attention, and one is surprised to find no reference to the work of Cajander and his disciples. Wide though the survey of literature has been—there are 606 references in the bibliography, many of which are European—there are, therefore, important omissions.

These criticisms, however, only tend to throw into relief the wide field covered and the general usefulness of the book to foresters, whether in the embryo stage at universities or at work in the forest of any and every type. The illustrations are adequate and good, and the book is well bound.

NOTICES

Department of Scientific and Industrial Research. Report of the Forest Products Research Board, for the period ended 30th September, 1928. Price 3*s*. H.M. Stationery Office, Adastral House, Kingsway, W.C. 2.

THIS report is a comprehensive and well illustrated work which gives the reasons which led to the establishment of the board, its history up to the present time, and an account of the work carried out by the different departments of the Laboratory. There are sections dealing with wood technology, timber physics, seasoning, timber mechanics, wood preservation, wood-working, mycology, entomology, wood chemistry, and utilization, and the report provides a useful means for all interested to quickly find out what is the present state of knowledge in these subjects, as well as to learn what work is in progress. Although labelled a 'Report' it is in fact a small text-book, covering in outline the different subjects detailed above, and as such should be invaluable to a wide circle, student, practitioner and researcher, both in the growing and utilization of timber. A list of publications by the Board and its officers is given.

The Practice of Silviculture, by RALPH C. HAWLEY. Chapman & Hall, Ltd., London, 1929. Price 20*s*.

THIS is the second edition of a work first published in 1921, which has been rewritten and brought up to date. It is written primarily from the point of view of the United States of America and its scope is as follows. Chapters II to VIII deal with systems of regeneration, the clear-cutting, seed tree, shelterwood, selection, coppice and coppice with standards methods being described. Then follow three chapters on intermediate cuttings, thinnings, &c., and one chapter each on methods of controlling cutting and slash disposal. The remaining nine chapters deal with forest protection, against fire, insects, disease, domestic animals, wild life, and natural phenomena. The practice of giving literature references at the end of each chapter is followed, and an appendix defining terms used in forestry provided. As a text-book it does not cover the field of the practice of silviculture in Britain and many other countries, but the chapters on slash disposal and protection against fire will be of interest to many foresters, and be useful for forestry students. There are a considerable number of text-figures, but no other illustrations.

Le Sol et la Forêt, by E. HESS. *Annales de la Station fédérale de Recherches forestières*, Tome XV. 1, Zurich, 1929, pp. 5–30.

FORESTERS are now taking greater interest in soils, and this article provides a summary of what is known regarding them in relation to the forest. The following are the salient points in the different sections.

Introduction. The treatment of soils under agriculture and silviculture are contrasted: in the former manures and cultivation are the basis of practice, while in the latter the fertility of the soil is influenced principally, if not entirely, through cultural operations on the crop. The effect of such operations on the soil should therefore always be considered.

Concentration of Hydrogen Ions in the Soil. The acidity of a soil resides in the presence

of free ions of hydrogen. The degree of ionization of pure water forms the basis of the determination of acidity, neutrality, and alkalinity. In each litre of pure water there are 10^{-7} gramme of hydrogen ions. To each ion of free hydrogen there is a hydroxyl ion, hence a solution is neutral when it contains an equal number of these two ions. In practice only the content of hydrogen ions is indicated, and the neutral point is designated pH = 7, i. e. by the negative logarithm of the quantity in grammes of the hydrogen ions in a litre of water. If one adds a quantity of acid, it disassociates to a certain degree into its constituent ions, hydrogen and x. There is then an inequality between the number of free hydrogen and hydroxyl ions, the hydrogen ions increasing, hence the pH falls. Conversely, when a base is added the pH rises. The following scale gives the terms applied to different pH values:

pH	4	5	6	7	8	9	10
	strongly acid	acid	slightly acid	neutral	slightly alkaline	alkaline	strongly alkaline

When the addition of a certain quantity of base or acid to a solution does not modify essentially its content of hydrogen ions, it contains buffer substances such as phosphates and bicarbonate of soda.

The pH is important in relation to the chemical, physical, and biological condition of the soil, and has been stated to have some relationship with plant diseases.

Climate and Soil. Climate, and above all humidity, exercises a great influence on soil formation. The humidity of a soil depends on precipitation and evaporation, and the balance between these differentiates soil type. The strata of a soil profile are called : *A*, the horizon in contact with the vegetation ; *B*, resting on the mother rock ; and *C*, the mother rock. In humid climates such as in this country, where precipitation exceeds evaporation, the balance of the water filters through the soil removing soluble substances from the *A* horizon, and depositing them on the *B* horizon. The alkalis, potassium, sodium, calcium and magnesium are removed first, and the sesquioxides of iron and aluminium subsequently. These two stages produce two soil types common in Europe both on the continent and in this country; soils with a decalcified but not decolorized *A* horizon are termed Brown Earths, and soils with the iron and aluminium also removed podsols. Conversely, in arid climates, the water movement is upwards and the *A* horizon is enriched. Rainfall therefore, is an important factor in soil development, and with or without temperature is the basis for several soil classifications.

The Influence of Vegetation on the Formation of Soils. The impoverishment of the superficial layers of soil is not due only to climate, the vegetative covering of the soil influences in a marked degree the chemical and physical nature of the soil. This influence is due in no small part to the rate of decomposition of the plant detritus which in turn depends principally on temperature. For example, in Northern Europe decomposition is very slow, and acid humus accumulates, and this acidity by rendering the various salts more soluble hastens leaching. The vegetative covering by its influence on the chemical and physical properties of soil prepares the soil for other associations.

Relation between pH and Tree Species. The hydrogen-ion concentration of a soil plays an important role in distribution of plants and associations. Amann and Braun-Blanquet have given the following classification:

1. Acid-loving species	associated with	soils of	pH	6·7–4·0.
2. Neutral	do.	do.	do.	7·0–6·7.
3. Base	do.	do.	do.	7·5–7·0.
4. Indifferent	do.	do.	do.	very variable.

Frank, as the result of analyses of forest soils in Germany, has concluded that the ability to tolerate acidity decreases in the following order: spruce, silver fir, beech, and larch. In order to determine the influence of different species in the soil, Hesselman has carried out analyses of tree leaves at the time of defoliation. From these data he made the following classification:

1. Much acid material, and little alkaline matter capable of buffering: all coniferous species except larch, also *Calluna vulgaris*, *Vaccinium myrtillus*, *Empetrum nigrum*, and *Hylocomia*.
2. Little acid material, and a certain quantity of buffer substances: birch, alders, aspen, willows, beech, ash, and herbaceous plants.
3. Very little acid material and much alkaline matter: hazel and the elms.
4. Much acid and alkaline material: oaks, larch.
5. Little of either material: some grasses, e. g. *Deschampsia flexuosa*.

It is for this reason that the use of soil-improving species such as hazel, birch, alder, beech, &c., particularly in mixture with coniferous species is now receiving so much attention in Europe.

The Hazel. Because of the important place which hazel species occupies in combating soil acidity its status in Switzerland is discussed.

The Influence of Cultural Operations on the Quality of Soils. Cultural operations including the choice of species also have an important effect on the soil. The growth of pure stands of conifers, particularly spruce and pine under certain conditions, leads to soil impoverishment, through the accumulation of raw humus. At Bärenthoren the introduction of oak under pine raised the pH from 3·6 to 4·7, although oak is not the best species from this point of view. Similarly under-thinning may lead to soil degradation. The holding of reserves of timber in a stand is, therefore, irrational from the soil as well as from the financial point of view.

Acid Humus and the Natural Regeneration of Forests. Nemec has shown that almost all the nitrogen necessary for the development of tree species is provided by the decomposition of organic substances in the dead covering of the soil. The humus layer, therefore, is an important reservoir of nutrients for the growth of trees, but its condition and the rate of decomposition must be considered. If raw humus accumulates regeneration is difficult, and here again the use of broadleaved species with conifers is important. Mixing the humus with the soil is also beneficial under certain conditions.

The Influence of Fire on the Soil. Numerous instances are known of the favourable growth of trees on burnt sites, where growth is otherwise difficult; this is particularly so on raw humus types. Fire not only increases the amount of soluble salts of potassium, but may also have a beneficial effect on the physical condition of clay soils.

The Liming of Forest Soils. The acidity of a forest soil could be neutralized by lime, but the amounts necessary are large, and periodic applications would be necessary.

Application of the Principles expressed in Previous Sections. The fact that forest trees show a certain difficulty in reproducing themselves naturally under their own canopy is generally recognized. This phenomenon may be explained by a change in the superficial horizons of the soil. A notable instance is the effect of pure stands of spruce. A layer of raw humus is formed, which is matted together with fungal mycelium, evaporation is reduced and air does not penetrate into the soil. The aerobic bacteria are reduced directly and by the increase in protozoa, and the effect on the root development of the tree is unfavourable. A rotation of species is unnecessary because favourable conditions can be maintained by the admixture of broadleaved species, or in mountains where such

will not live, of different shrubs. After clear cutting the acidity of a soil decreases temporarily, and this has led Salisbury to advocate the coppice system under which the crop is cut frequently. When a soil is exposed in this way, however, it may suffer a serious degradation in physical condition as has been shown by Burger and Wittich.

Note on some Forest (Site) Types in North America, by Dr. Yrjö Ilvessalo. Reprinted from *Acta Forestalia Fennica*, 34, 1929, 111 pp. and 16 plates.

THOSE who are interested in Cajander's theory of forest types will welcome this study of its application to conditions in North America. In view of the great extent of country, and the fact that the author was not primarily visiting America for this work, the survey is incomplete and fragmentary compared with the work on Finland, and is chiefly interesting as an application of the methods to a new area. A considerable amount of space is given, however, to the growth of *Pinus murrayana* (contorta) on different types, and this will be of special interest to foresters in this country in view of the possibility of this species proving a useful tree on certain peat and other poor soil types.

A Tree-classification and Thinning System, by Lauri Ilvessalo. Reprinted from the *Acta Forestalia Fennica*, 34, 1929, 15 pp.

THIS paper by the gifted Finnish forester who died last year will interest those who for purposes of research or teaching have to consider different systems of tree-classification to aid and define thinning practice. It is based on Schotte's system, modifications of which are now used in most countries. Four canopy classes are defined 1 to 4, and each class is subdivided into four sub-classes: trees of perfect stem and crown, with no letter designation, trees with defective crowns designated *a*, trees with defective stems *b*, and *c* injured, diseased and dying trees. Sub-classes *a* and *b* are further subdivided into three classes to give a more detailed description of each tree.